Texas ~~State~~ [. Interagency Natural Resources Council.

THE COASTAL RESOURCES MANAGEMENT PROGRAM OF TEXAS

APPENDICES
to the
INTERIM REPORT

Edited by
James T. Goodwin
Joe C. Moseley

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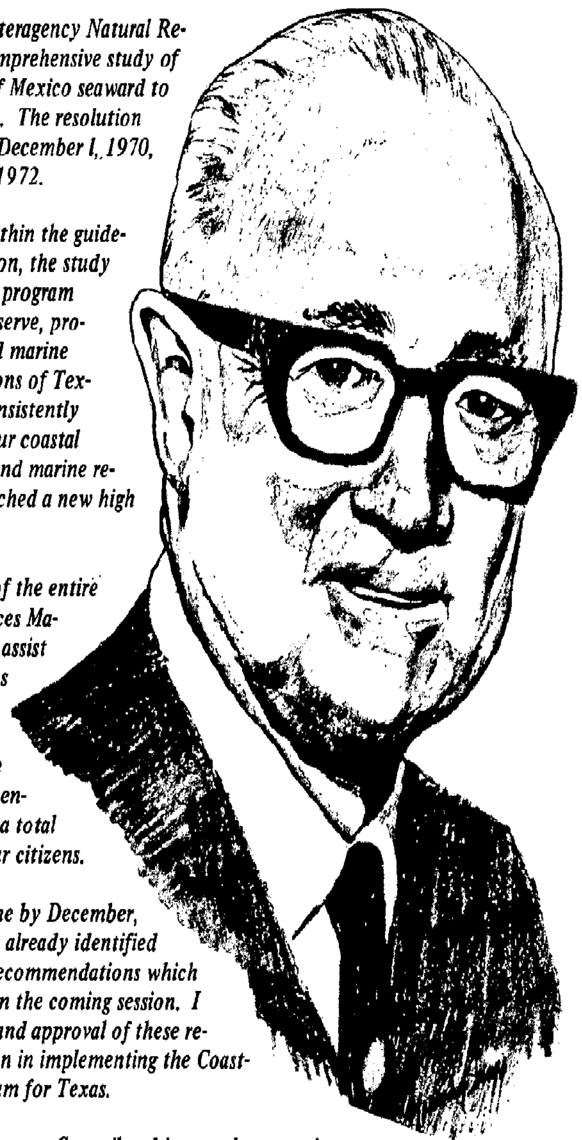
COASTAL RESOURCES MANAGEMENT PROGRAM

Members of the Legislature and Fellow Texans:

As Governor of Texas and Chairman of the Interagency Natural Resources Council, a consortium of State agencies, I am pleased to transmit the Appendices to the Interim Report to the 62nd Legislature on the Coastal Resources Management Program of Texas. This effort was authorized by S.C.R. No. 38 passed by the 61st Legislature 1st Session and funded in the Division of Planning Coordination within my Office.



S.C.R. No. 38 directed the Interagency Natural Resources Council to conduct a comprehensive study of the Coastal Zone and the Gulf of Mexico seaward to our State's territorial boundaries. The resolution called for an Interim Report by December l, 1970, and a final report in December, 1972.

At the Council's direction, within the guidelines established by the Resolution, the study is designed to result in an action program through which the State can preserve, protect, and develop our coastal and marine environment for future generations of Texans. This Administration has consistently emphasized the importance of our coastal resources to the State. Coastal and marine related activities in Texas have reached a new high during the past two years.

It is my hope as well as that of the entire Council that the Coastal Resources Management Program of Texas will assist the Legislature in coming to grips with the problems of our coastal areas. It is also our hope that this Program will serve as a model for studying regional environmental problems as part of a total interrelated system to benefit our citizens.

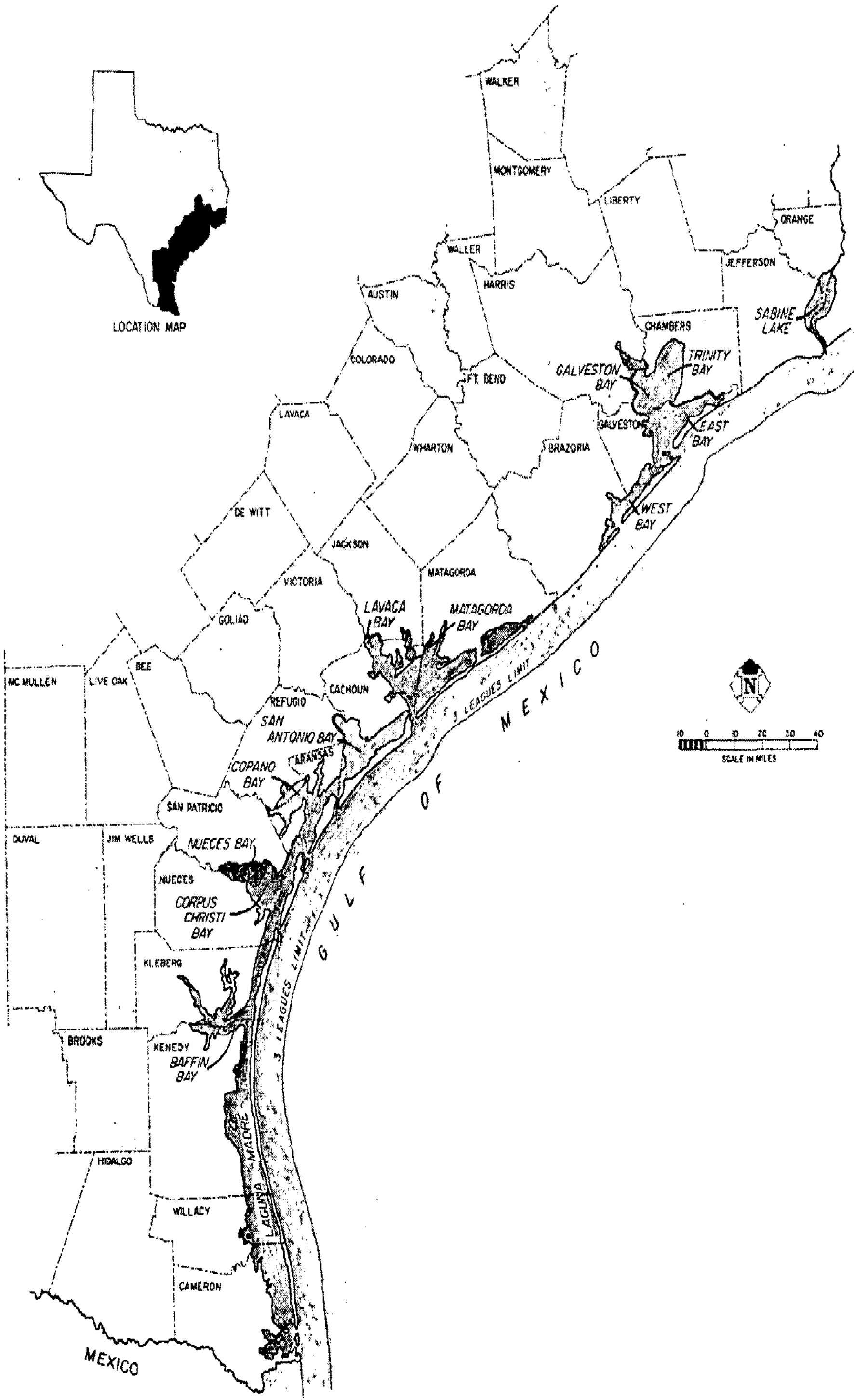
Much work remains to be done by December, 1972. However, the Program has already identified specific problems and presents recommendations which need your immediate attention in the coming session. I urge your careful consideration and approval of these recommendations as the first action in implementing the Coastal Resources Management Program for Texas.

The Interagency Natural Resources Council and its member agencies pledge their continued support in working with you on coastal environmental problems and other matters related to our invaluable natural resources.

Sincerely,

Preston Smith

Preston Smith
Governor of Texas



LOCATION MAP
WALKER
MONTGOMERY
LIBERTY
ORANGE
SIANA
WALLER
HARRIS
JEFFERSON
AUSTIN
CHAMBERS
SABINE LAKE
TRINITY BAY
GALVESTON BAY
COLORADO
FT. BEND
GALVESTON
EAST BAY
LAVACA
WHARTON
BRAZORIA
WEST BAY
DE WITT
JACKSON
MATAGORDA
VICTORIA
LAVACA BAY
MATAGORDA BAY
GOLIAD
MC MULLEN
LIVE OAK
BEE
CALHOUN
REFUGIO
SAN ANTONIO BAY
ARANSAS
COPANO BAY
3 LEAGUES LIMIT
GULF OF MEXICO
SAN PATRICIO
DUVAL
JIM WELLS
NUECES BAY
NUECES
CORPUS CHRISTI BAY
KLEBERG
BROOKS
KENEDY
BAFFIN BAY
LAGUNA MADRE
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MANAGEMENT PROGRAM OF TEXAS

APPENDICES

to the

INTERIM REPORT

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Joe C. Moseley

THE INTERAGENCY NATURAL

RESOURCES COUNCIL

1971

ACKNOWLEDGEMENTS

The Interagency Natural Resources Council wishes to give special acknowledgements for assistance in preparing and reviewing this report to the following organizations and agencies.

Federal Water Quality Administration, U. S. Army Corps of Engineers, Soil Conservation Service, U.S.D.A., Bureau of Sport Fisheries and Wildlife, Bureau of Outdoor Recreation, Bureau of Reclamation, Office of Water Resources Research, Department of Housing and Urban Development, Southern Regional Environment Conservation Council of the Southern Governor's Conference, Texas State Department of Health, Sea Grant Program of Texas A & M University, Texas Transportation Institute at Texas A & M University, Bureau of Economic Geology of the University of Texas at Austin, Center for Research in Water Resources at the University of Texas at Austin, Institute of Marine Law at the University of Houston, Texas Tech University, Local governments along the Coast, Councils of Governments along the Coast, River Authorities, Members of the Texas Ports Association, Texas Water Conservation Association, Gulf Coast Waste Disposal Authority, Galveston Bay Study Group, Mid-Continent Oil and Gas Association, Trans-Continental Gas Pipeline Corporation, Humble Oil & Refining Co., Inc., Dow Chemical Co., Inc., Shell Oil Co., Inc., Central Power & Light Co., Inc., Houston Lighting and Power Co., Inc., Gulf States Utilities Co., Inc., Bank of the Southwest, American Society for Oceanography, National Audubon Society, Texas Sportsman Club, Houston Sportsman Club, American Society of Civil Engineers, Texas Conservation Council, and the Conservation Foundation.

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This Report was coordinated and written by the following staff in the Office of the Governor's Division of Planning Coordination:

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INTRODUCTION

The Coastal Zone of Texas contains the most diverse grouping of valuable natural resources in the State. Its problems are complex and its boundaries are imprecise. The great rivers of Texas empty their waters and water-borne wastes into the bays and estuaries of the Coastal Zone where they react with the waters of the Gulf. Urban centers in this area are attracting an increasing population with resultant demands on natural resources generating significant environment change.

Fortunately, much of man's impact upon the Coastal Zone has been concentrated in nodes of urban development such as the Houston-Galveston area. Much of the Coastal Zone is relatively unspoiled. This fact will enable us, through proper study and action, to safeguard the environmental integrity of the Coast for future generations of Texans, while fully utilizing coastal resources.

The Coastal Resources Management Program will examine the natural resource base for undesirable symptoms, define problems, and present solutions within an area of Texas extending from the Sabine River to the Rio Grande and from about 80 miles inland to the three league boundary in the Gulf. It will not only examine each resource separately, but also as each resource related to all others in an environmental system.

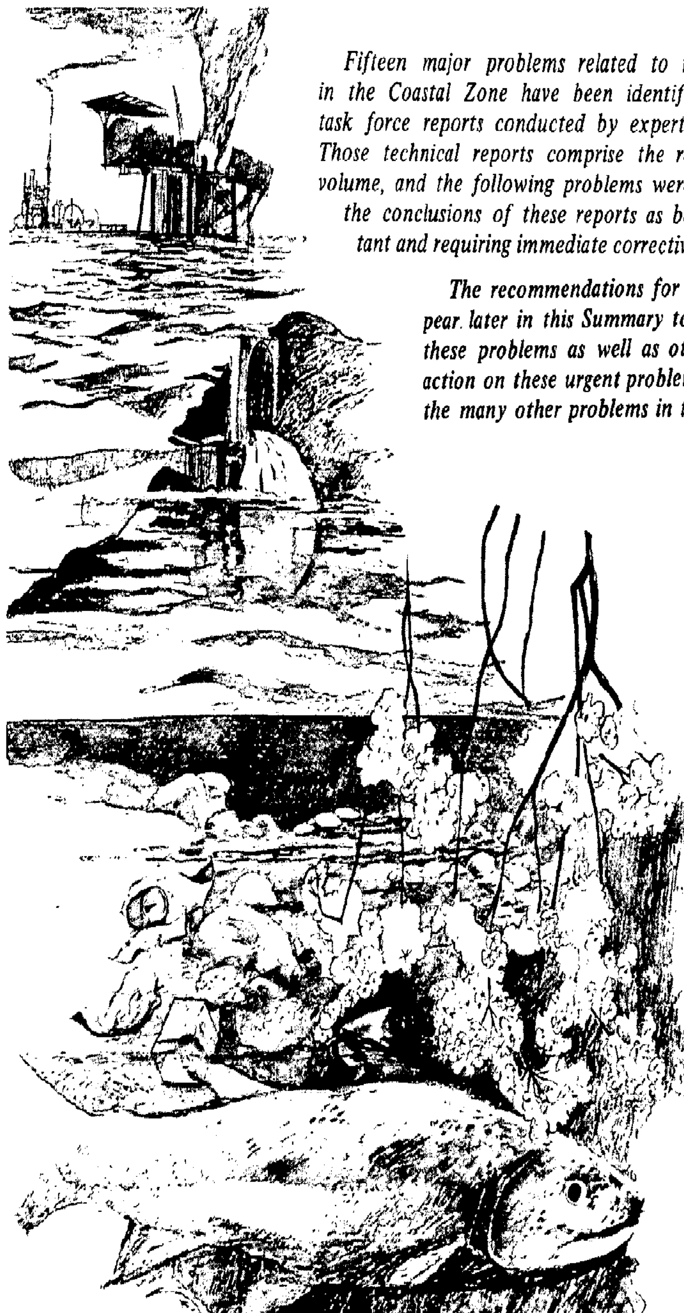
The Coastal Zone of Texas is an extremely valuable resource for the people of this State. It should be conserved, developed and preserved to serve the goals of the people while respecting individual rights. The area's value to Texas cannot be measured by economic benefits alone. The social value of our coastal environment is high for those who live and work there, as well as for all other Texans.

Natural resources are defined here as those things existing in a state of nature which are of either actual or potential economic or social value to man. They are often grouped under broad categories such as land, water, air, fish and wildlife, minerals and vegetation.

These resources are limited in quantity and therefore in use. While some resources such as water are well suited for multiple use, others are not. Certain uses complement each other with no serious effect on the total environment and others are mutually exclusive. The same land resource cannot be used for suburban development and a wildlife refuge. It should be recognized that the use of land impacts in different ways upon other resources. Each link in the chain of natural resource uses must be carefully traced to determine ultimate effects on society.

Problems of natural resource use are normally related to the use of the land or water resource. Possible solutions, as will be noted later, indicate that the key to coastal resource management is the proper understanding and management of the land and water resources of the Coastal Zone.

State and local governments have a responsibility to insure the preservation of unique resources, replenishment of renewable resources and conservation of irreplaceable resources. Man's role in his environment demands income and employment opportunities as well as leisure pursuits. Texas can assist man to improve his living standard and surroundings in the Coastal Zone while maintaining a desirable balance with nature. The goals of man and nature do not have to be mutually exclusive.



Fifteen major problems related to natural resources in the Coastal Zone have been identified from the 20 task force reports conducted by experts in their fields. Those technical reports comprise the remainder of this volume, and the following problems were extracted from the conclusions of these reports as being both important and requiring immediate corrective steps.

The recommendations for action which appear later in this Summary touch on all 15 of these problems as well as others. Corrective action on these urgent problems will impact on the many other problems in the Coastal Zone.

IMMEDIATE PROBLEMS

● Fish and wildlife resources may be and sometimes are destroyed by the runoff from urban and agricultural land areas as well as discharge of inadequately treated municipal and industrial wastewaters into the bays, estuaries and their tributaries. Unwise use and development of water resources can have a similar impact. This presents a potential health hazard and aesthetic eyesore to man.

- Ill-defined boundaries coupled with dynamically shifting landforms, unavailable public information, and a heretofore poorly defined State policy toward the use of its coastal lands results in unwise development and poor management in the Coastal Zone.

- Wildlife habitat is being destroyed and potential park land lost through urban/industrial expansion and environmental degredation, which adversely affects recreational opportunities.

- Limited public access to beaches of the Gulf Coast hampers recreational pursuits.

- The existing structure of State laws, regulations, and governmental management is inadequate to deal with the complex, diverse, and dynamic problems of the Coastal Zone.

- The 200 million dollar a year commercial fishing industry is in danger of collapse due to institutional barriers, inadequate insurance availability, international competition, low utilization of technology, and archaic legal regulation, and badly needs the State's assistance.

- Lives are lost and property destroyed or damaged by severe hurricanes on the average of once every two years.

- The effect of diminishing mineral resources on the Coastal Zone's economic and financial base is not understood and is not being examined.

- The Coastal Zone's aquatic ecosystems are seriously threatened by numerous and diverse physical processes such as poor drainage, land subsidence, sedimentation, erosion, accretion, dredging, bulkheading, and alteration of estuarine circulation patterns. These dangers, while more subtle than waste discharges, are very real.

- Discharge of gases and particulates into the atmosphere creates a health hazard, presents a nuisance, and causes property damage.

- Improper and inadequate solid waste disposal practices pollute both air and water and create health hazards from rats, flies, and other disease sources.

- Present methods of extracting minerals have adversely altered the environment and will continue to do so until economically feasible alternatives are developed which do otherwise.

- Growth, combined with rapid advances in transportation technology, necessitates coordinated, long-range transportation planning, especially concerning super-draft port facilities and transfer points between various types of transportation.

- The heritage of Texas, represented by its many cultural and historical sites, is being lost to unplanned urban and commercial expansion.

- Frequent minor oil and chemical spills are cumulatively very damaging to the Coastal Zone environment.

AN ENVIRONMENTAL SYSTEM

Approaching the environment as a balanced system is the cornerstone of the Coastal Resources Management Program. The system approach both ties the parts together and establishes priorities for decisions.

Any attempt to define the complex relationships which form an environmental system is doomed to failure. The system operates under conditions which are infinitely more complex than our minds can comprehend, even with the aid of computers. However, man makes decisions daily which affect the environment and he must attempt to understand their consequences.

The Coastal Resources Management Program has attempted to understand the environmental complexities of the Coastal Zone by breaking the environment into the twenty study areas represented by the following reports, examining them separately and then looking at the ways they react with all the other components. In this way a simple artificial environment has been created which is, at least, a beginning towards understanding the complex.

Both direct and indirect effects of a change in an environmental system must be understood. A direct effect can be explained as a first order effect between two or more task areas such as the direct effect on fish of polluted waters. An indirect effect is the second or third order effect as the system change reverberates through the entire system. An example might be the effect on financial institutions of decreased commercial fisheries catches which stem from the depletion of fish resulting from water pollution. In this example, the impact of water pollution upon financial institutions is traced through several intermediate steps.

While the previous example includes facets of biology, chemistry and society, the direct and indirect effects are similar in other types of systems. Of course, each task area is a system within the larger environmental system. An impact on part of the smaller system can have direct and indirect effects within it and upon other sub-systems as well. If we affect any link in the biological food chain, the balance of nature is upset and the system changes to a new equilibrium condition. Problems arise when the system cannot naturally cope with the change, in which case, the sub-system may be eradicated. This leaves a void with many attendant complex possibilities. It is in hopes of understanding some of these effects that the environment is being studied as a complex system.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- The Coastal Zone of Texas represents an invaluable, and, in many respects, irreplaceable resource to the State and Nation. Its economic value is great. Greater still is its total social and economic value as a living, working, and recreational environment for man and nature as they interact one with the other.

- The inevitable pressures of urban, commercial, industrial, and agricultural growth are causing a general degredation of the Coastal Zone environment which will worsen unless steps are taken to balance preservation, conservation, and development through a Coastal Resources Management Program.

- If Texas does not move ahead with its own program in coastal management, the Federal Government will develop one for us; Texas cannot afford this because: (1) State and local cooperation insures a responsiveness to unique local conditions, and (2) State and local groups can maintain better controls, do a better job and do it at less cost.

- The agencies and institutions of the State acting in concert through the Interagency Natural Resources Council and armed with the mandate of S.C.R. No. 38 comprise the logical team to develop a plan and implement a program for managing Texas' coastal resources. The participation of private, local, and Federal interests must be and has been insured. No program that may be developed can succeed or even begin without the support of the Legislature.

- The remainder of the development phase of the Program should concentrate on coastal environmental problems, their solution, and the legalistic mechanisms necessary for full implementation of the Program.

SPECIFIC ACTION

It is recommended that the 62nd Legislature:

- Provide to the individual agencies comprising the Interagency Natural Resources Council sufficient funds to assure that each agency's activities in support of the Coastal Resources Management Program might be carried out, and provide the Executive Office with sufficient funds for continuing the coastal activities of the Council, including the Coastal Resources Management Program.

- Give careful consideration to the recommendations of Legislative Interim Committees as those recommendations relate to the natural resources and environmental problems of the Coastal Zone. Special attention should be given to recommendations with regard to land use and pollution controls and interagency cooperation.

- Continue to define and improve the responsibilities and roles of the State agencies pertaining to natural resources of the Coastal Zone.

• It is also recommended that the 62nd Legislature direct the Interagency Natural Resources Council to provide the mechanism through which significant coordination will be achieved. Specific tasks to be performed by the Council working with the appropriate agencies include the following:

1. Delineate the role and responsibility under existing statutes of each State agency in matters pertaining to the natural resources of the Coastal Zone;

2. Work with the General Land Office and the Attorney General in establishing a comprehensive policy concerning coastal lands, including: (a) policies on the sale and subsequent use of Texas' submerged lands, (b) clarification of ownership of lands resulting from erosion/accretion shifts, (c) delineation of limits of state and private ownership, and (d) equitable compensation for all economic uses of State lands;

3. Give every assistance to member pollution control agencies in their continued anti-pollution activities;

4. Work directly with the Institute of Marine and Coastal Law and other experts on legal problems of coastal resource management;

5. Work with the Coordinating Board for Higher Education, State supported universities and colleges, the Advisory Council for Technical-Vocational Education and the Texas Education Agency in encouraging the development of marine-related curricula and conservation education at all levels;

6. Investigate the feasibility of applying procedures of resource analysis developed in the Coastal Resources Management Program to other areas of the State;

7. Work with the Texas Water Quality Board, the Parks and Wildlife Department, the Texas Water Rights Commission, the Texas Water Development Board, the Air Control Board and other concerned agencies in investigating problems associated with power plant siting;

8. Coordinate with the Texas Historical Survey Committee and provide through the Coastal Resources Management Program for preserving culturally and historically significant sites which might be destroyed or affected by natural resource use;

9. Assist the Governor in establishing an Interagency Transportation Council and coordinate with that Council on matters related to transportation's effect on land use and resources in the Coastal Zone.

INVESTIGATIONS

During the two years remaining for development of the final report on the Coastal Resources Management Program, the Interagency Natural Resources Council should, through its member agencies and other qualified parties conduct investigations of:

1. Existing pollution problems in-

cluding those unrelated to waste disposal; their sources, long-term effects and solutions;

2. The environmental effects of proposed hurricane protection measures;

3. A legal analysis of institutional authority and responsibility necessary for the proper implementation of a Coastal Resources Management Program;

4. An inventory of remaining mineral resources, replenishable or alternative substitutes for those resources, and means by which to extract those resources with minimal environmental losses.

5. The long-term effect of persistent man-made substances such as oils, farm chemicals, and pesticides upon the natural environment;

6. The use of a multi-disciplinary approach in developing a practical and usable method for evaluating the consequences of alternative environmental management proposals including the assessment of consequences of varying land-use patterns;

7. Means of supporting research leading to a better understanding of hurricane forecasting as well as mitigating their destructive effects;

8. Data availability for preparation of a comprehensive sourcebook of existing marine resources in the Gulf;

9. Means by which to encourage and support research in marine culture;

10. The cost to future Texans of unnecessarily depleting economically important non-replenishable resources, including effects on long-term income and employment opportunities;

11. Evaluating the economic potential of resource utilization in the Coastal Zone.

PERSONAL ACTION

Each of us can, through our individual actions, impact on the environment. In addition to the avoidance of such things as littering, the individual should take positive steps to inform his local, State or Federal government of action they can and should take to protect the environment. The individual citizen should take special care to work closely with his State legislator. The concerned citizen should be active, never passive, when his environment is at stake.

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CONTINUING EFFORTS

The Interagency Natural Resources Council is proceeding with the development of a Coastal Resources Management Program for Texas under renewed guidance by the 62nd Legislature. S.C.R. No. 38, the original mandate given to the Council, has been expanded and redirected towards the solution of specific problems with passage of S.C.R.s 8 and 9 in May of this year. The November, 1971, Quarterly Progress Report to the Legislature will contain a detailed work plan for the December, 1972, report to the Legislature as directed by S.C.R. No. 38. The text of all three resolutions forming the authority for the Program follows in the next section of this report.

SENATE CONCURRENT RESOLUTION NO. 38

WHEREAS, The state-owned submerged lands, islands, estuaries, and estuarine areas in the Texas Gulf Coast Area, including the submerged lands of the state seaward of the mean of lower low water marks in the Gulf of Mexico, and the natural resources and the environmental natural beauty with which they are so richly endowed, constitute an important and valuable property right belonging to the Public Free School Fund and to all of the people of Texas, and they are of immediate and potential value to the present and future generations of Texans; and

WHEREAS, It is the declared policy of the state that such submerged lands, islands, estuaries, and estuarine areas shall be so managed and used as to insure the conservation, protection, and restoration of such submerged lands, islands, estuaries, and estuarine areas with resources and natural beauty and, consistent with such protection, conservation and restoration, their development and utilization in a manner that adequately and reasonably maintains a balance between the need for such protection in the interest of conserving the natural resources and natural beauty of the state and the need to develop these submerged lands, islands, estuaries, and estuarine areas to further the growth and development of the state; and

WHEREAS, The people of the State of Texas have a primary interest in the correction and prevention of irreparable damage to or unreasonable impairment of the uses of the coastal waters of the state and inland waters of the state in such estuaries and estuarine areas caused by drainage, waste water disposal, industrial waste disposal, and all other activities that may contribute to the contamination and pollution of such waters; and

WHEREAS, The people of the State of Texas also have primary interests in the value of such lands, islands, estuaries, and estuarine areas as public property for production and marketing of oil and gas and other minerals and mineral resources, for the production of living resources, for shell and other fisheries and fishing, hunting, and other recreation, for wildlife conservation, and for health and other uses in which the public at large may participate and enjoy; and

WHEREAS, It is also the declared policy of this state that the public, individually and collectively, shall have the free and unrestricted right of ingress and egress to and from the state-owned beaches bordering on the seaward shore of the Gulf of Mexico and hence the people of the State of Texas have a further primary interest in conserving the natural beauty of the state's beaches and protecting and conserving them for the use of the public; and

WHEREAS, A comprehensive study is necessary to prepare the way for constructive legislation for the present and future protection of the interests of the people of the State of Texas in such submerged lands, beaches, islands, estuaries, and estuarine areas; and

WHEREAS, The United States Government is now conducting similar studies studies under P.L. 660 of the 84th Congress as amended and under P.L. 90-454 of the 90th Congress and is entitled to receive the full cooperation of the agencies of this state with respect to the lands, beaches, waters, estuaries, and estuarine areas of this state; now, therefore, be it

RESOLVED, By the Senate of the State of Texas, the House of Representatives concurring, that the following be accomplished:

Section 1. The Interagency Natural Resources Council, an interagency planning entity created under the authority of House Bill 276, Acts 1967, 60th Legislature, Regular Session, Chapter 417, in consultation with the School Land Board and the Submerged Lands Advisory Committee and with all other appropriate local, state, and federal agencies, is authorized and directed to make a comprehensive study of the state's submerged lands, beaches, islands, estuaries, and estuarine areas, including but without limitation coastal marshlands, bays, sounds, seaward areas, and lagoons, The term "estuary" means all or part of the mouth of an intrastate or interstate river or stream or other body of water, including, but not limited to, a sound, bay, harbor, lagoon, inshore body of water, and channel, having unimpaired natural connection with the open sea and within which the sea water is measurably diluted with fresh water derived from land drainage. The term "estuarine areas" means an environmental system consisting of an estuary and those transitional areas which are constantly influenced or affected by water from an estuary such as, but not limited to, coastal salt and freshwater marshes, algal flats, coastal and intertidal areas, sounds, bays, harbors, lagoons, inshore bodies of water, and channels. For the purpose of the study or studies of these lands, beaches, islands, estuaries, and estuarine areas, the Council shall consider, among other matters (a) their wildlife, health, and recreational potential, their ecology, their value as natural marine, anadromous, and shell fisheries, their value as established marine soils for producing plant growth of a type useful as nursery or feeding grounds for marine life and their natural beauty and esthetic value, (b) their importance to navigation, their value for flood, hurricane, and erosion control, their mineral value, and (c) the value of such areas for more intensive development for economic use to further the growth and development of the state. The study or studies shall also include (a) studies of the various problems of coastal engineering such as the protection of the beaches and bay bluffs from harmful erosion, the design and use of groins, seawalls, and jetties, and the effects of bay fills, fish passes, and other coastal works upon the physical features of the shores, channels, and bay bottoms and upon marine life and wildlife inhabiting such areas and (b) studies of the effects of waste and drainage water discharges into the waters of such estuaries and of the Gulf of Mexico in relation to the reasonable protection and conservation of the marine environment and the natural resources and natural beauty of these submerged lands, beaches, islands, estuaries, estuarine areas, and their overlying waters. In conducting the study or studies, the Interagency Natural Resources Council shall consider, among other matters, and without limitation as to the generality thereof, the physical and economic effects of existing and proposed water development projects of federal, state, and local agencies, and of authorized and prospective drainage projects of whatever nature upon the coastal waters and the waters of the state's estuaries and estuarine areas, the feasibility of reclaiming drainage waters from such projects, the future population growth and economic development in the area and in areas tributary thereto, the effects of existing and proposed projects for the filling and reclamation of waterfront lands upon the waste assimilative capacity of the coastal waters and the waters of the state's estuaries and estuarine areas, the possibilities of reclamation and reuse of waste waters and drainage water from such projects, and the feasibility of flow augmentation through managed releases from upstream reservoirs as an aid to quality maintenance.

Sec. 2. The Interagency Natural Resources Council may receive grants and matching funds from and may contract with such state, federal, or local public agencies or private agencies, entities, or educational institutions as it deems necessary for the rendition and affording of such management and technical services, facilities, studies, and reports, and personal services and operating expenses as will best assist it to carry out the purposes of this concurrent Resolution.

Sec. 3. The Interagency Natural Resources Council of Texas is directed to call on the advice, counsel, and guidance, and participation of appropriate local, state, and federal departments, boards, agencies, and educational institutions. The council shall, to the fullest practicable extent, cooperate and coordinate its work with all departments, boards, and agencies undertaking planning and technical investigations pertinent to this study. The Interagency Natural Resources Council is directed to coordinate its study and, in order to avoid duplication of work, shall make maximum use of data and information available from state agencies and boards and federal agencies, including but not limited to the United States Public Health Service, the United States Corps of Engineers, the United States Department of Health, Education and Welfare, the Federal Water Pollution Control Administration, the United States Soil Conservation Service, the United States Fish and Wildlife Service, the United States Bureau of Reclamation, the United States Geological Survey, the United States Department of the Interior, the member agencies of the Interagency Natural Resources Council, and the Bureau of Economic Geology of The University of Texas.

Sec. 4. The Interagency Natural Resources Council is authorized to hold one or more public hearings which it deems necessary or desirable for the full development of all facts pertinent to its studies. City, county and state officials, officers, and employees and those of any other political subdivision of the state and of the state government are directed to furnish the Council, upon its request and within the limits of their respective facilities, such data, reports, and any other information it may require in connection with its studies, without any cost, fee, or charge whatsoever.

Sec. 5. On or before the first day of December, 1970, preceding the 1971 Regular Session of the Legislature, the Interagency Natural Resources Council shall submit to the Governor of Texas and to the Legislature a progress report indicating the status of its studies to date together with any recommendations for emergency legislation at that time to carry out the purposes of its studies as herein defined.

Sec. 6. The Interagency Natural Resources Council shall submit its final report to the Governor of Texas and to the Legislature on or before the first day of December, 1972, preceding the 1973 Regular Session of the Legislature, together with its findings and recommendations for appropriate legislation to carry out the purposes of its studies as herein defined.

SENATE CONCURRENT RESOLUTION NO. 8

Authorizing and directing the Interagency Natural Resources Council to provide the mechanism to promote interagency cooperation and coordination with regard to land use, pollution control and other problems in the Coastal Zone; working with the appropriate agencies, to delineate the roles and responsibilities of the State agencies concerned with the protection, conservation, and development of the State's coastal resources; to work with the State agencies in solution of certain urgent problems adversely affecting those resources; and to take certain other actions.

WHEREAS, By Senate Concurrent Resolution No. 38, the 61st Texas Legislature, Regular Session, authorized and directed the Interagency Natural Resources Council to make a comprehensive study of the State's submerged lands, beaches, islands, estuaries and estuarine areas, including, but without limitations, coastal marshlands, bays, sounds, seaward areas and lagoons, and to submit a progress report to the Governor of Texas and to the Legislature by the first day of December 1970 and its final report by the first day of December 1972; and

WHEREAS, These coastal resources of the State of Texas are of great value to the present and future generations of Texans; and

WHEREAS, It is the declared policy of the State that such submerged lands, islands, estuaries, and estuarine areas shall be so managed and used as to insure the conservation, protection, and restoration of such submerged lands, islands, estuaries, and estuarine areas with resources and natural beauty and, consistent with such protection, conservation and restoration, their development and utilization in a manner that adequately and reasonably maintains a balance between the need for such protection in the interest of conserving the natural resources and natural beauty of the State and the need to develop these submerged lands, islands, estuaries, and estuarine areas to further the growth and development of the State; and

WHEREAS, The people of the State of Texas have a primary interest in the correction and prevention of irreparable damage to or unreasonable impairment of the uses of the coastal waters of the State and inland waters of the State in such estuaries and estuarine areas caused by drainage, waste water disposal, industrial waste disposal, and all other activities that may contribute to the contamination and pollution of such waters; and

WHEREAS, The Summary of the Interim Report on the Coastal Resources Management Program submitted by the Interagency Natural Resources Council pursuant to Senate Concurrent Resolution No. 38, 61st Legislature, Regular Session, calls attention to a number of urgent and serious problems adversely affecting the State's coastal resources and the coastal environment, to the fact that the respective roles and responsibilities of the several State agencies with respect to the State's coastal resouces and the coastal environment are not clearly defined in some instances, that there is need for coordination and cooperation among the State agencies, and recommends that certain actions be taken as soon as possible; and

WHEREAS, It is in the best interests of the people of Texas and the desire of the Legislature that all possible actions be effectively taken by the Interagency Natural Resources Council and the State agencies within their statutory powers to protect, conserve and properly develop the State's coastal resources and to improve the coastal environment pending submission of the Council's final report; now, therfore, be it

RESOLVED, By the Senate of the State of Texas, the House of Representatives concurring, that the following be accomplished:

Section 1. The Interagency Natural Resources Council is authorized and directed to:

1. Promote interagency cooperation and coordination in actions affecting the State's coastal resources;

2. Working with the appropriate agencies, delineate the roles and responsibilities of the State agencies as set out by statute in matters pertaining to the natural resources of the Coastal Zone;

3. Work with the General Land Office and the Attorney General in establishing a comprehensive policy concerning coastal lands, including: (a) policies on the sale and subsequent use of Texas' submerged lands, (b) clarification of ownership of lands resulting from erosion/accretion shifts, (c) delineation of limits of State and private ownership, and (d) equitable compensation for all economic uses of State lands;

4. Give every assistance to member pollution control agencies in their continued anti-pollution activities;

5. Work directly with the Institute of Marine and Coastal Law and other experts on legalistic problems of coastal resouce management;

6. Work with the Coordinating Board for Higher Education, State-supported universities and colleges, the Advisory Council for Technical-Vocational Education and the Central Education Agency in encouraging the development of marine-related curricula, conservation education, and marine-related research programs;

7. Investigate the feasibility of applying procedures of resources analysis developed in the Coastal Resources Management Program to other areas of the State;

8. Work with the Texas Water Quality Board, the Texas Parks and Wildlife Department, the Water Rights Commission, the Water Development Board, the Air Control Board and other concerned agencies in developing a consistent and logical policy for power plant siteing;

9. Coordinate with the Texas Historical Survey Committee and provide through the Coastal Resources Management Program for the preservation of culturally and historically significant sites which might be destroyed or affected by natural resource use; and

10. Coordinate with the Interagency Transportation Council on matters related to transportation's effect on land use and resources in the Coastal Zone.

11. Cooperate and coordinate with other advisory bodies established by the Legislature.

Sec. 2. The Interagency Natural Resources Council is authorized and directed to meet in open session at least once every quarter. The time, place, and agenda of the quarterly meeting shall be made known to the public at least ten (10) days in advance of the meeting.

Sec. 3. The Interagency Natural Resources Council shall report activities and progress of the Coastal Resources Management Program to the members of the Legislature at least once every three months until the final report is submitted by December 1972.

Sec. 4. The results of the actions of the Interagency Natural Resources Council pursuant hereto shall be incorporated in its final report on the Coastal Resources Management Program, to be submitted by December 1972.

SENATE CONCURRENT RESOLUTION NO. 9

Authorizing and directing the Interagency Natural Resources Council in its Coastal Resources Management Program to conduct certain important environmental, legal and economic investigations relating to the protection, conservation and development of Texas' coastal resources and the coastal environment.

WHEREAS, The Interagency Natural Resources Council is conducting the Coastal Resources Management Program, a comprehensive study of the State's submerged lands, beaches, islands, estuaries and estuarine areas, including, but without limitation, coastal marshlands, bays, sounds, seaward areas and lagoons, pursuant to Senate Concurrent Resolution No. 38 of the 61st Texas Legislature, Regular Session; and

WHEREAS, The Summary of the Interim Report submitted by the Interagency Natural Resources Council to the 62nd Texas Legislature, Regular Session, pursuant to said Senate Concurrent Resolution No. 38, finds that the Coastal Zone of Texas, representing an invaluable social and economic, and in some respects irreplaceable resource to the State and Nation, is experiencing pressures of urban, industrial, and agricultural growth that are causing a general degradation of the environment, that such conditions will worsen unless steps are taken to maintain a balance of conservation and economic development, and that the Coastal Resources Management Program during the next two years should concentrate on coastal enviornmental problems, their solution and the legalistic mechanisms necessary for full implementation of the Program; and

WHEREAS, It is in the best interests of the people of Texas and the policy of the Legislature that the coastal environment be upgraded and maintained at a high level; now, therefore, be it

RESOLVED, By the Senate of the State of Texas, the House of Representatives concurring, that the following be accomplished:

Section 1. The Interagency Natural Resources Council in its Coastal Resources Management Program, working through its member agencies and other qualified parties, is authorized and directed to conduct studies of and encourage cooperation in the following:

1. Existing pollution and environmental problems including those unrelated to waste disposal, including information concerning their sources, long-term effects and solutions;

2. The environmental effects of proposed hurricane protection measures and other man-made additions to and modifications of our Coastal Zone;

3. A legal analysis of institutional authority and responsibility necessary for the proper implementation of a Coastal Resources Management Program;

4. An inventory of remaining mineral resources, replenishable or alternative substitutes for those resources, and means by which to extract those resources with minimal environmental losses;

5. The long-term effects of man-made substances such as oils, farm chemicals and pesticides upon the nautral environment;

6. The use of a multidisciplinary approach in developing a practical and usable method for evaluating the consequences of alternative environmental management proposals including the assessment of consequences of varying land-use patterns;

7. Means of supporting research leading to a better understanding of natural meteorological and geological phenomena such as hurricanes, northers, subsidence, erosion, etc., with a view toward minimizing destructive effects;

8. The availability of data for preparation of a comprehensive sourcebook of existing marine resources in the Gulf;

9. The Tektite Program of the Marine Biomedical Institute of the University of Texas Medical Branch at Galveston, and various research programs related to Coastal Zone resources with a view toward encouragement and support of marine-oriented research;

10. The cost to future Texans of unnecessarily depleting economically important nonreplenishable resources, including effects on long-term income and employment opportunities; and

11. Evaluation of the economic potential of resource utilization in the Coastal Zone.

Sec. 2. The Interagency Natural Resources Council will include the findings of these investigations and studies in its final report on the Coastal Resources Management Program to the 63rd Texas Legislature.

THE CLIMATE AND PHYSIOGRAPHY OF THE TEXAS COASTAL ZONE

Prepared by

Texas Water Development Board

John W. Kane, Hydrometeorology Unit

October 1970

for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

CONTENTS

THE CLIMATE AND PHYSIOGRAPHY OF THE TEXAS COASTAL ZONE

I. *OVERVIEW*

Physiographers (e.g., Fenneman and Johnson, 1946) have classified the entire Coastal Zone of Texas as part of the West Gulf Coast Section of the Coastal Plain Province. The immediate Coastal Zone is almost uniformly flat and low with a gradual increase both in height and relief to the north and west. The Coastal Plain Province terminates abruptly at the Balcones Escarpment which generally follows a Del Rio-San Antonio-Austin line. North of Austin, the transition is less abrupt, but follows approximately a line from Austin through Dallas to the Oachita Mountains in Oklahoma.

A significant feature of the Texas Coast is the line of peninsulas and off-shore islands which separates all the major bays, estuaries, and lagoons along the coast from the open Gulf of Mexico. These embayments are important commercial fishery areas in themselves and in addition provide spawning grounds for many commercially important species. Because the off-shore islands restrict tidal exchange, the quantity and quality of drainage from the land surface is of extreme importance to the biota of these bays, estuaries, and lagoons.

The climate of the Texas Coastal Zone is in general subtropical with long warm to hot summers and short mild winters. The average annual temperature (Fig. 1) shows a fairly regular decrease with latitude from about 74° F. at Brownsville to about 70° F. at Sabine Pass. In contrast to the north-south variation of temperature, the average annual precipitation varies from east to west from about 55 inches per year at Sabine Pass to about 26 inches per year at Brownsville (Fig. 2). On the basis of the spatial and seasonal distribution of temperature and precipitation, Thornthwaite distinguishes four climatic belts along the Texas Coast (Fig. 3).

II. *REGIONAL CLIMATIC PATTERNS*

Upper Coast - The upper coast in this discussion coincides with Thornthwaite's humid zone. In Texas, the zone extends from Louisiana westward to West Galveston Bay.

The climate is predominantly marine. Humidity is high, and precipitation is abundant and fairly evenly distributed throughout the year although there is a slight maximum in the summer. This summertime maximum may be attributed to local convective activity associated with the sea breeze circulation and tropical disturbances from the Gulf of Mexico.

During the summer, afternoon temperatures are typically lowered along the coast by the sea breeze which is an on-shore wind resulting from temperature differences between the land and sea surfaces. Frequently convergence in the low-level wind field caused by the sea breeze circulation leads to afternoon and evening rain showers.

Winters are typically mild. Invasions of cold continental air masses usually last only two to three days depending on the intensity of the system before the mild southerly air-flow which prevails in this season returns bringing warmer temperatures. The climatological expectation is for from five to ten days during the winter with temperatures 32% F. or below. The mean date of the first freezing temperature is December 15, while the mean date of the last freezing temperature is February 15. Snow is rare, with the mean annual snowfall less than one inch. Spring and Fall in this zone generally resemble the summer climate with occasional cooler periods resulting from invasions of modified polar air masses.

Middle Coast - The middle coast extends from western Galveston Bay to southern Corpus Christi Bay. Thornthwaite (Fig. 3) distinguishes *two climate types, wet subhumid and dry-subhumid,* in this zone however, this distinction is based mainly on total precipitation. The climate in this zone becomes progressively drier and more continental toward the west and south. The precipitation regime here is more characteristic of that in most of the interior of the State, that is, there is a maximum of precipitation in the late spring with a secondary maximum in early fall. The average annual precipitation in this zone decreases fairly regularly to the west from about 46 inches to about 34 inches (Fig. 2).

Mainly because of the irregularity of the coastline in this zone and the barrier islands, the sea-breeze circulation in summer is less well developed here than on the upper coast, although it does have significant cooling effects near the shoreline. Convective activity associated with the sea-breeze circulation contributes less to the summer rainfall in the area so that the May-September maxima common to the interior are evident in the average annual distribution of rainfall.

Cold air masses traversing this area in late fall, winter, and early spring are usually considerably modified by the time they reach the coast. Mean annual number of days with temperatures of 32% F. or below is about five or less. On the average, freezing temperatures occur between December 15 and February 15 in common with the upper coast. Snow is rare. The climatological expectation of days with temperatures of 90% F. or above rises to about 90 per year in this area in contrast with only about 60 days per year in the upper coast zone.

Lower Coast - The lower coast extends from southern Corpus Christi Bay to the Rio Grande. Thornthwaite (Fig. 3) classified the climate *as semi-arid.* Average annual precipitation ranges from about 34 inches along the coast in the north to about 26 inches at the mouth of the Rio Grande (Fig. 2). Precipitation decreases fairly rapidly inland to the west so that Mission only about 50 miles from the coast along the Rio Grande has an annual average of less than 20 inches. The monthly distribution of precipitation in this area exhibits maxima in May and September.

Summers are long, hot, and relatively dry in this zone. The slight cooling effect of the sea breeze circulation, and the small amount of summer cloudiness in this area are evidenced by the fact that the mean annual number of days with maximum temperature of 90% F. and above is about 90 near the coast but increases to 120 or more about 50 miles inland. Spring and Fall resemble Summer here, with more rain and slightly more moderate temperatures.

Winters are short and mild. The mean length of the freeze-free period in this zone is about 330 days. Freezing weather occurs on the average from less than two days in the south to about five days per year in the north part of the lower coast. Cold air masses which penetrate as far south as the lower coast in winter are much modified in passage so that temperature changes in this zone are much less pronounced than those in the Austin area for example. Only about once in ten years on the average do cold outbreaks severe enough to damage winter crops and fruit trees occur in this area.

III. HURRICANES

Historical Patterns - Hurricanes have struck the Texas Coast throughout history, some with disastrous results. There is no reason to believe that there will be any striking change in either the frequency or the pattern of future hurricanes affecting Texas (Fig. 6). The frequency with which hurricanes strike Texas shows considerable variation, there have been hurricane-free periods of up to six years (1903-1908) followed by years of higher frequency. In both 1933 and 1942 two hurricanes struck Texas. *Based on the record from 1900 to the present, it can be expected that on the average, a hurricane will strike somewhere on the Texas Coast about once in two years.*

Hurricanes which affect Texas form in the southern North Atlantic, the Carribean Sea, and the Gulf of Mexico. The most favorable location for formation of these hurricanes varies from month to month in the hurricane season which extends from June through October. Hurricanes occasionally form in the period November through May, but none are known to have affected Texas in these months. About two-thirds of the hurricanes which have struck Texas have occurred in August and September, while the remaining one-third have occurred in June, July, and October.

Hurricanes develop from easterly waves in the zone of convergence between the northeast and southeast trade winds which is located as much as twelve degrees north of the equator in August. Easterly waves are common in the tropics. An easterly wave will pass a given station in the trade wind belt twice a week on the average. Most easterly waves are stable and may travel thousands of miles with no further development, but occasionally, when conditions are favorable, an easterly wave will become unstable and will intensify further becoming a tropical cyclone.

Tropical cyclone is the generic term for all cyclonic circulations developing over tropical waters. Four stages in the development of a tropical cyclone are distinguished: *tropical disturbance, tropical depression, tropical storm, and hurricane.* The stages are marked by increasingly well organized rotary circulation and higher wind speeds (Fig. 7). A hurricane, for instance, has pronounced rotary circulation and maximum winds of *74 miles per hour* or more.

A tropical cyclone on reaching land or recurving over the cooler water of the North Atlantic may dissipate, or it may take on extra-tropical characteristics and continue its path of destruction far to the north. All tropical cyclones have the potential for producing extreme rainfall when passing inland; the hurricane, of course, being the most intense stage of tropical storm development, poses the additional threat of damage from high tides, wind, and tornados.

IV. HURRICANE DESTRUCTION

Tides and Wave Action - By far, the greatest destruction and loss of life along the Texas Coast have resulted from a *combination of hurricane tide and wave action.* As a hurricane approaches the coast, water is piled up to the right of the hurricane's path by the on-shore wind (Fig. 4). When coupled with astronomical high tide and the rise in water level because of the low atmospheric pressure within a hurricane, abnormally high tides of the order of *15 feet* may be produced on the open coast (Fig. 5). Still higher tides have been observed in bays along the coast.

A particularly destructive feature of some hurricanes is the *storm surge* the explanation of which is not well understood. The storm (or hurricane) surge is a rapid rise in water level of several feet in a few seconds which coincides approximately with the arrival of the center of the storm. During the September 8, 1900, hurricane at Galveston in which about 6,000 lives were lost, Dr. I. M. Cline who was then in charge of the Weather Bureau at Galveston describes a *sudden rise of water level of four feet in as many seconds.*

Wind - Representative wind readings during hurricanes are scarce for several reasons. Even if wind instruments are installed in an area where a hurricane strikes they usually fail before maximum wind speeds are reached. Most wind instruments which are strong enough to withstand hurricane winds have considerable inertia and do not indicate gusts accurately. Tests with specially installed "gust meters" have indicated that hurricane gusts may exceed the steady wind by 50 percent, thus in a steady 150 m.p.h. wind, gusts might reach 225 m.p.h.. In spite of the lack of data it seems likely that most hurricanes have steady winds of 100 m.p.h. at some time in their life cycle, 150 m.p.h. winds are not uncommon, and in some extreme cases winds have exceeded 200 m.p.h..

The force exerted by the wind on a structure increases as the *square of the wind speed*. Engineers have estimated that while a 60 m.p.h. wind exerts a force of 15 pounds per square foot, a 150 m.p.h. wind exerts 112 pounds per square foot. Actual force on a structure may exceed one and a half times the direct frontal pressure, depending on the shape of the structure, because of negative pressure on the leeward side.

Added to the dynamic force of the wind is the *energy contained in heavy, wind-blown debris* which may damage or destroy a building which could otherwise withstand the wind pressure. Flying debris has been responsible for many deaths and injuries in past hurricanes. Fortunately, the windspeed in most hurricanes decreases rapidly as the storm moves inland. Hurricane Celia (August, 1970) was a notable exception in that not only did most of the damage in the coastal area result from high winds (maximum reported 161 m.p.h.), but it still produced 90 m.p.h. gusts as far inland as Del Rio.

Flooding - Next to wave and tide action, hurricane floods are the second greatest source of deaths, injuries, and damage. As a hurricane moves inland, the winds tend to be retarded by surface friction and to blow more directly inward toward the storm center thus increasing low-level convergence and the rainfall rate. When the vertical motion induced by the increased convergence is added to lifting by higher terrain or a frontal surface, torrential rains can result. *Twenty to thirty inches of rain* during the passage of a dissipating hurricane are not unusual. While this amount of rainfall in a period of a few days may produce long-lasting high water in flat, low flying areas near the coast, only water damage to buildings, furnishings, crops, and equipment usually result with much inconvenience but little loss of life among the inhabitants. But in hilly or mountainous regions catastrophic floods may result with heavy flood damage and great loss of life. Runoff from hurricane rains may greatly decrease the salinity of coastal embayments temporarily.

Hurricane Beulah (1967) is an example of a hurricane producing widespread and extensive damages from flooding. While two other Texas storms have produced higher rainfall rates (Hearne, June, 1899 - 24 inches in 24 hours; and Thrall, September, 1921 - 38.2 inches in 24 hours), Beulah stands alone when the extent of heavy rains is considered (Fig. 9). All Texas streams from the Nueces south and west to the Rio Grande and streams in northeast Mexico experienced flooding following the passage of Beulah. Floods on many of these streams were greatly in excess of previous record floods. Fortunately, Beulah turned to the south and west after crossing the coast rather than following the more normal path to the northeast which would have taken it through the more densely populated and highly developed central and northeastern portions of Texas in which case damages and loss of life would likely have been even greater.

Hurricane Tornados - Tornados are frequently reported in association with the passage of hurricanes. It is likely that many tornado occurrences are unobserved amid the general destruction of a hurricane passage. Study of hurricane tornados indicates that they occur only in the forward semicircle or along the advancing periphery of the storm and that they are generally less severe than the usual inland tornado with a shorter and narrower path.

Hurricane Beulah was also unique in the number of reported tornados. The E.S.S.A. State Climatologist for Texas has confirmed reports of *115 tornados* associated with this storm from areas as widely separated as Houston and Austin. The most severe of these occurred at Palacios where three persons were killed and five were injured.

V. HURRICANE PROTECTION

Existing Protection - Hurricane protection work along the Texas Coast has taken the form of protection from storm tides and waves by *sea walls* and *levees*, and by *drainage structures* to lessen damage from flooding. No protection is offered against hurricane winds and tornados although experience in other states has demonstrated that strict building codes in hurricane prone areas can reduce wind damage significantly.

The *Galveston Sea Wall* was the first protective structure to be constructed along the Texas Coast. It was constructed following the disastrous hurricane of 1900 and has since been improved and extended to offer additional protection to the city. Other hurricane protective structures are located at Port Arthur, Texas City-La Marque-Hitchcock, Corpus Christi, and at Freeport. Other small scale protective works exist but are probably inadequate for protection in a severe hurricane.

Future Plans - Historically, hurricane protective work has had to wait on development along the coast line and usually on the passage of a destructive hurricane through a highly developed area. However, the U. S. Army Corps of Engineers is presently investigating the feasibility of providing hurricane protection to the *entire coast of Texas* by erecting levees along the beaches and the barrier islands with secondary protective structures to protect developed areas along the inshore bays. These studies are scheduled to be completed in 1973.

It seems likely at this time that protection of the entire coast of Texas will prove *infeasible* from the standpoint of expected benefits and costs along many thinly populated sections of the coast, but the plan could serve as a guide for a future integrated protective system of the entire coast as development occurs.

Hurricane Warnings - Modern communications and surveillance of hurricanes by aircraft, radar, and satellites coupled with improved forecast techniques have greatly increased the time available to prepare for a hurricane. Such preparation may include mass evacuation of the threatened area, for instance, in Hurricane Carla (1961) an estimated 350,000 persons fled inland from the coastal areas of Texas and Louisiana. There is no doubt that the evacuation greatly reduced the death toll.

Especially needed in this connection is a foolproof forecast technique. Preparation for a hurricane in a highly developed area can be very costly, but of necessity, hurricane warnings are issued for larger areas than actually prove necessary to allow for last minute changes in path thus requiring some areas to prepare unnecessarily. Many scientists are studying the problem and better understanding of the *process of tropical cyclone genesis* will probably lead to improved forecasts and possibly to reduction of the intensity of hurricanes which threaten coastal areas by some form of weather modification.

VI. CHARACTERISTIC GULF CURRENTS

Locations and Directions - The semi-permanent off-shore currents along the Texas Coast are governed by the main stream of the North Equatorial Current which enters the Gulf of Mexico through the Yucatan Channel. The eastern part of this flow turns to the right to flow out through the Florida Strait. The western part divides into two currents, one of which flows westward along the upper coast of Texas while the other flows to the north along the lower coast. These two currents meet along the central coast of Texas in a convergence zone which is locally known as the *whirlpool of the Gulf*. The two semi-permanent along-shore currents along the Texas Coast as well as the convergence zone remain fairly constant from year to year, but shift in location and relative strength in response to seasonal changes in the prevailing wind. Winds and tides resulting from hurricanes and other tropical cyclones have only a transitory effect on these semi-permanent currents.

Seasonal Variations - Off-shore currents off Sabine Pass are to the west and those off the Rio Grande are to the north throughout the year. Winds influence only intensities and minor changes in direction of these currents and the location of the convergence zone.

During January, February, and March, the westward and southwestward current is well developed in response to the prevailing easterly winds during this season. The convergence zone is located off Aransas Pass. In May the winds shift to southeasterly and the northerly current off the lower coast extends further north shifting the convergence zone along the coast to the vicinity of the mouth of the Colorado River. This condition prevails during the summer with the northerly current along the lower coast reaching its greatest development. In September, the prevailing winds shift abruptly to the east and the convergence zone shifts to the southwest off Corpus Christi Bay. In the winter, the southwest nearshore current along the upper coast reaches its greatest development at the time when the prevailing winds have their most northerly component.

Performance as Pollutant Dispersers - Because the prevailing currents along the Texas Coast have an alongshore and in some cases an onshore component they function poorly as dispersers of pollutants. Alongshore currents carry sediments from the Mississippi, which drains most of the interior of the continent, for considerable distances along the Texas Coast. In these sediments, one finds much of the waste materials produced in the Central United States. Mississippi sediments have been identified as far to the west as the continental shelf off Rockport. It is reported that Rio Grande sediments are transported as far north as the Rockport vicinity, but there is some disagreement as to the extent of northward transport.

Surprisingly, in view of the importance of the Gulf of Mexico to the United States, Mexico, and Cuba, *little is known in detail of the ocean currents and circulation.* Since about two-thirds of the United States and more than half of Mexico contribute sediments - *and pollutants* - to the Gulf of Mexico, studies of ocean currents, circulation, and the effects of pollutants on the biota of the Gulf should have high priority.

VII. PHYSIOGRAPHIC FEATURES

Water Courses and Deltas - Texas is drained by ten major river systems which enter coastal bays, estuaries, and lagoons or empty directly into the Gulf along the Texas Coast. In order, from northeast to southwest, these are: the Sabine, Neches, Trinity, San Jacinto, Brazos, Colorado, Guadalupe, San Antonio, Nueces, and Rio Grande. In addition to these major systems, there are many minor coastal drainage systems which feed into the Gulf or the coastal embayments. Of the major streams, only the Brazos, Colorado, and Rio Grande empty directly into the Gulf. The Rio Grande normally has little or no flow at its mouth because of heavy demands in its lower reaches for municipal, industrial, and irrigation water.

Little delta building is presently taking place along the Texas Coast. There are many factors which influence this lack of delta building including the prevailing alongshore currents off the Texas Coast and the many upstream dams on Texas streams which considerably reduce the sediment load reaching coastal waters. In the case of rivers emptying into coastal embayments, the river water tends to ride over the denser saline water in the bays so that sediments are well distributed within the bays by local currents. The Trinity delta, for example, has built forward only approximately three tenths of a mile since 1855.

The most spectacular delta building episode occurred on the Colorado which had been dammed by a log jam prior to 1926 when the log jam was gradually cleared. Between 1930 and 1936, the Colorado delta built forward *four miles* across Matagorda Bay cutting the bay into two arms. The Colorado now has a direct exit into the Gulf. It is believed that the majority of the sediments used in the rapid delta building sequence had previously been trapped behind the log jam.

Estuarine and Beach Areas - The Texas Coast is an almost continuous series of bays, estuaries and lagoons from Sabine Lake through the Laguna Madre. The central depths of these embayments range from about four to thirteen feet except for areas near inlets, where local tidal currents may scour holes 30 to 40 feet deep, and dredged channels. The average rate of deposition in these bays is on the order of about *one foot per century* so that these embayments may be eliminated in less than a millenium unless there is a rise in sea level. Indications are that the Brazos River has already filled its bay. It now flows directly into the Gulf.

Texas bays penetrate about 30 miles inside the outer coast to the "bay line" where the gentle slope of the coastal plain limits inland progress of the bays. The bays are generally flanked by alluvial plains which in their lower ends are marshy in most places. Inside the bays there are fluvial plains flanking the river valleys. Seaward of the bays, there are barrier islands and barrier spits which protect them from the open Gulf. The shores of many bays, as well as the open coast and both sides of the barrier islands and spits have many miles of fine sandy beaches which provide excellent recreational areas.

VIII. IMPACTS ON DEVELOPMENT

Climate's Impact - The mild climate of the Texas Coast and the long frost free period have favored *agricultural* development. Crops range from rice, which requires large quantities of water, along the Upper Coast to forage in the drier sections. The Lower Rio Grande Valley where irrigation water is available produces large and varied crops mainly of fruit and vegetables as do other smaller areas in the lower and middle coastal zones. The climate of the Coastal Zone which permits outdoor activities year-round is attractive to *industry*, and an increasing *recreation*-based development is taking place in the area.

The main climatic hindrance to development is the threat of hurricanes, but the proximity to raw materials in the case of the petrochemical industry and other factors have outweighed this threat in many cases especially in areas where hurricane protection has been provided by sea-walls and levees.

Influence of Physiography - The coastal environment has led to the development of several major deep-draft ports along the Texas Coast. For this reason, among others, many industries which require access to world *shipping* lanes have located on the Texas Coast. An important *fishing* industry has developed in the area, and the proximity to both fresh water lakes and the bays and open Gulf attracts an increasing number of boating and sports-fishing enthusiasts each year. *Hunters* attracted to the coastal salt marshes, which are major wintering and breeding grounds for northern waterfowl, provide an important source of revenue.

Air Pollution - Air pollution along the Texas Coast has not previously been a widespread serious problem although local, temporary pollution episodes occur. Two factors have been responsible for the relative freedom from air pollution problems to date. First is the almost *universal use of natural gas* by industry in the Coastal Zone and little use of other less clean burining types of fuel. The other factor is the *naturally less stable stratification* of the lower atmosphere over the Texas Coast coupled with higher average surface winds which cause pollutants to be mixed throughout a deeper layer of the atmosphere than in air pollution prone areas.

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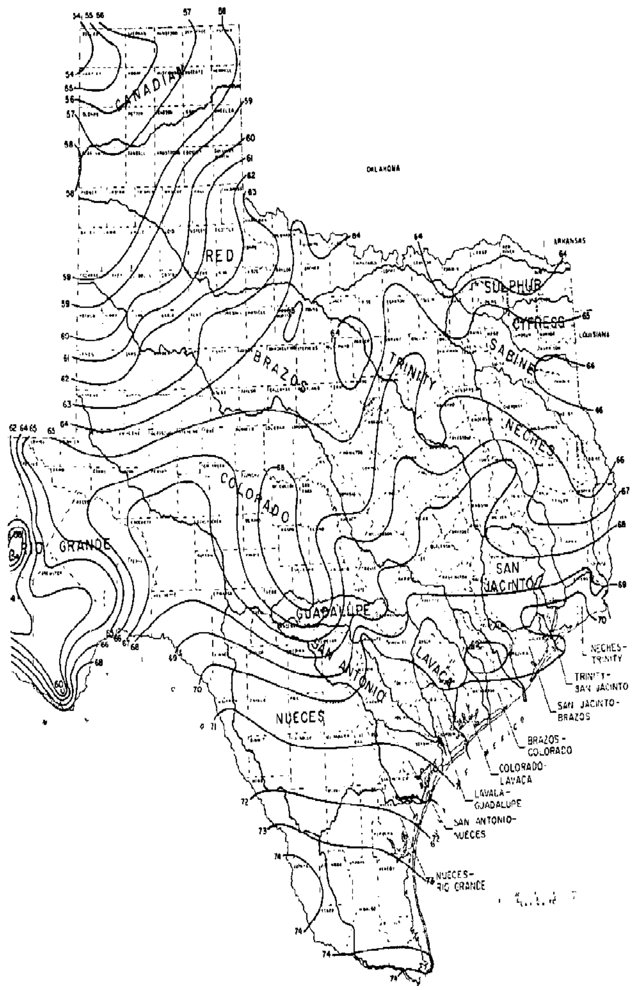
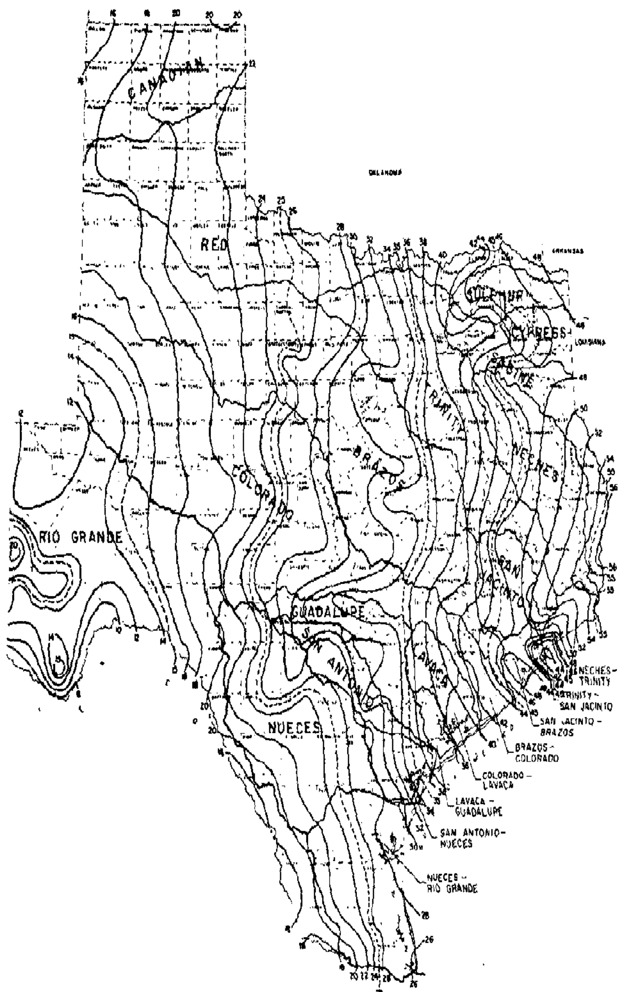


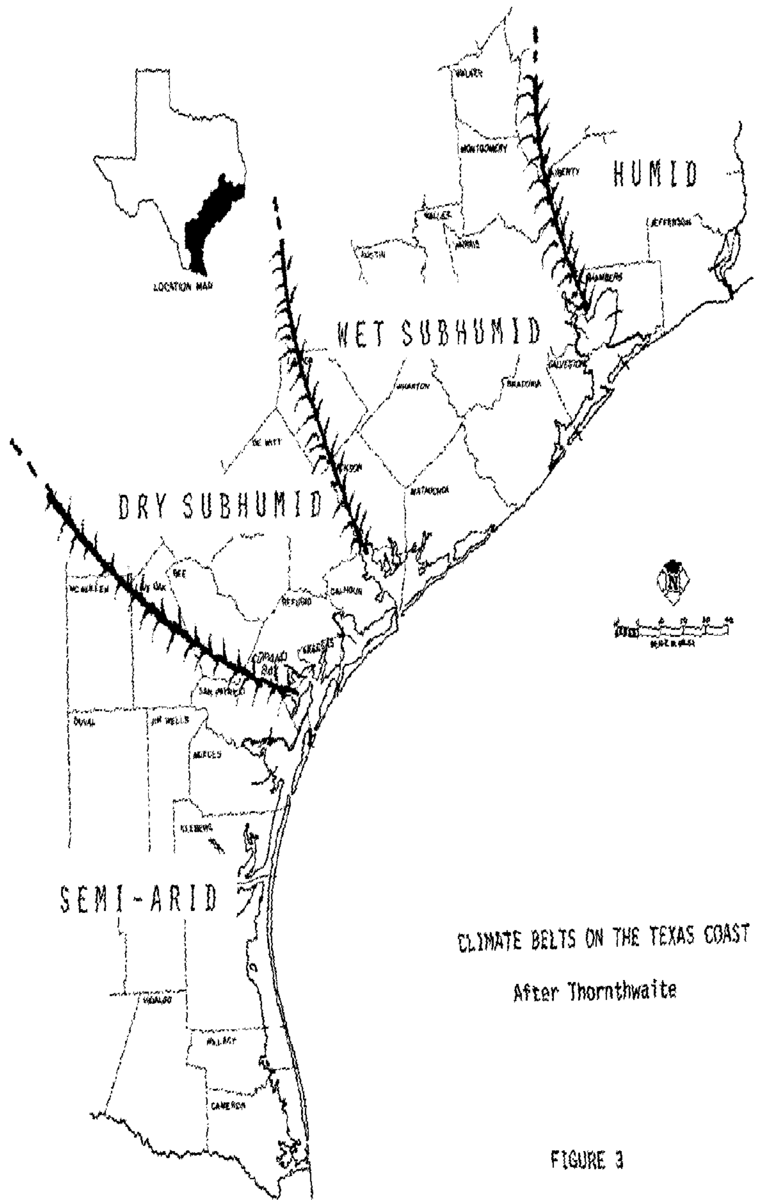
Average Annual Mean Free-Air
Temperature (Degrees Fahrenheit)
1931-60

FIGURE 1



Average Annual Precipitation
in Inches 1931-60

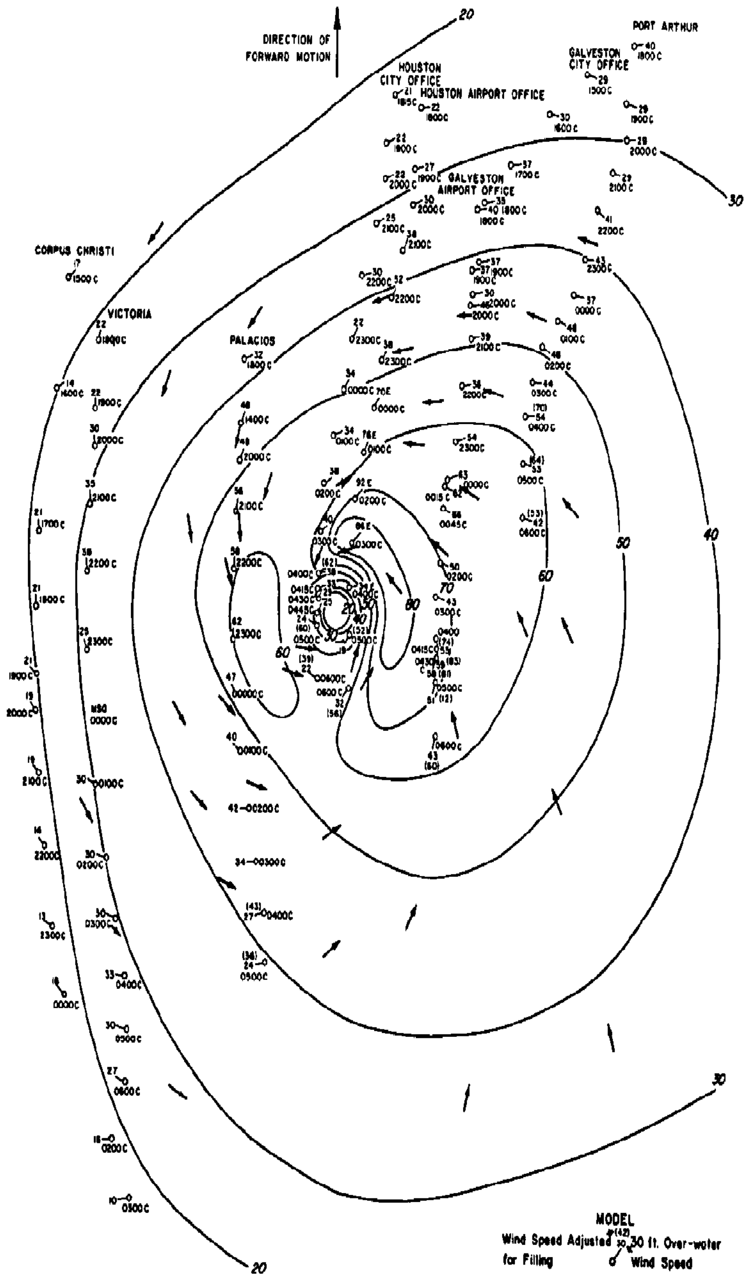
FIGURE 2



CLIMATE BELTS ON THE TEXAS COAST

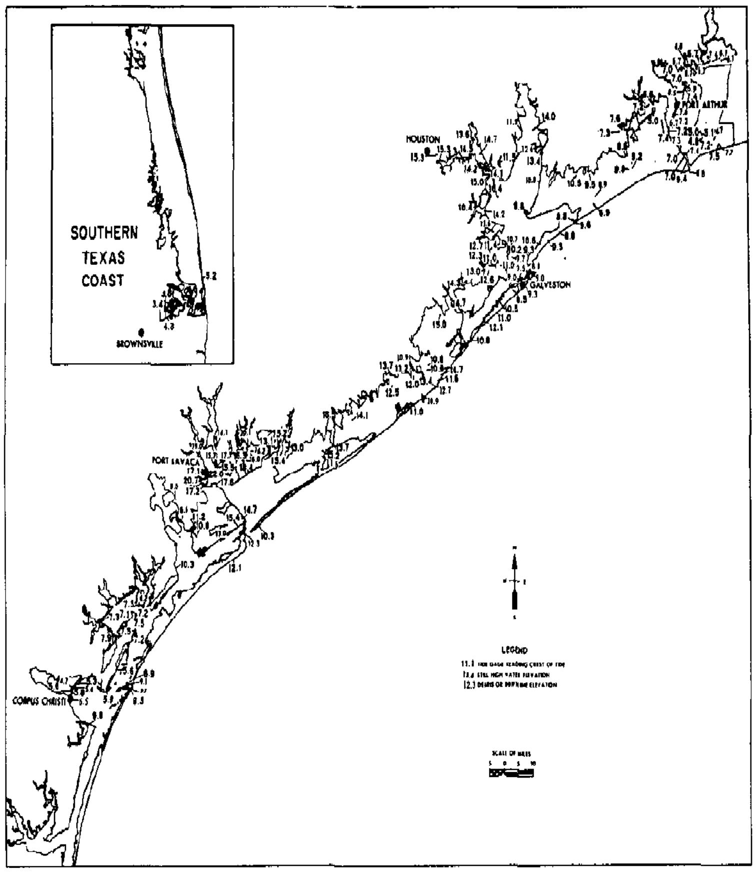
After Thornthwaite

FIGURE 3



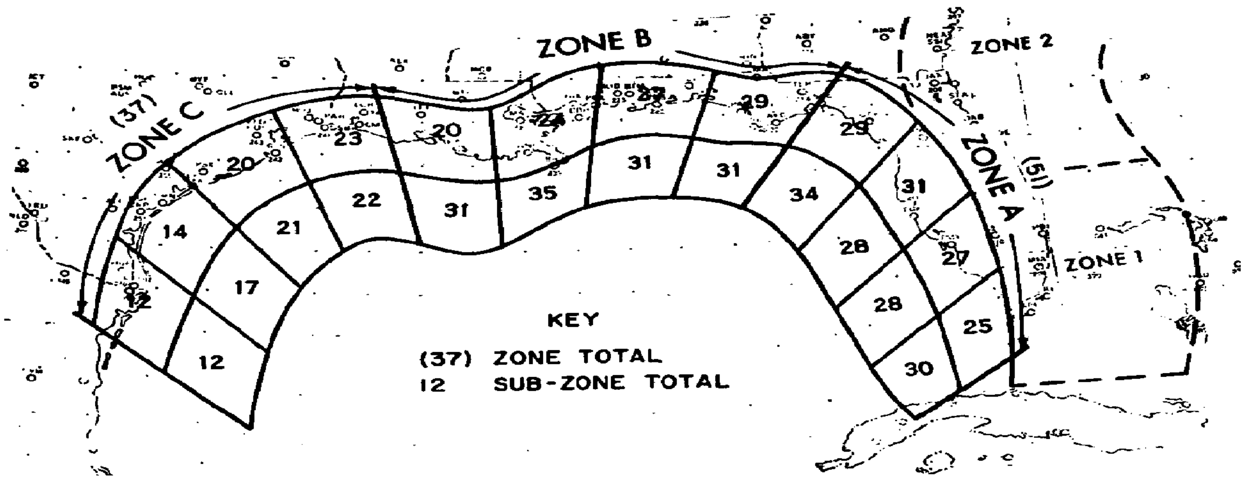
--Composite Wind-Speed and Direction Pattern, October 3, 1949, Near the Texas Coast. All times CST. Speeds in mph adjusted to 30 feet above water.

FIGURE 4



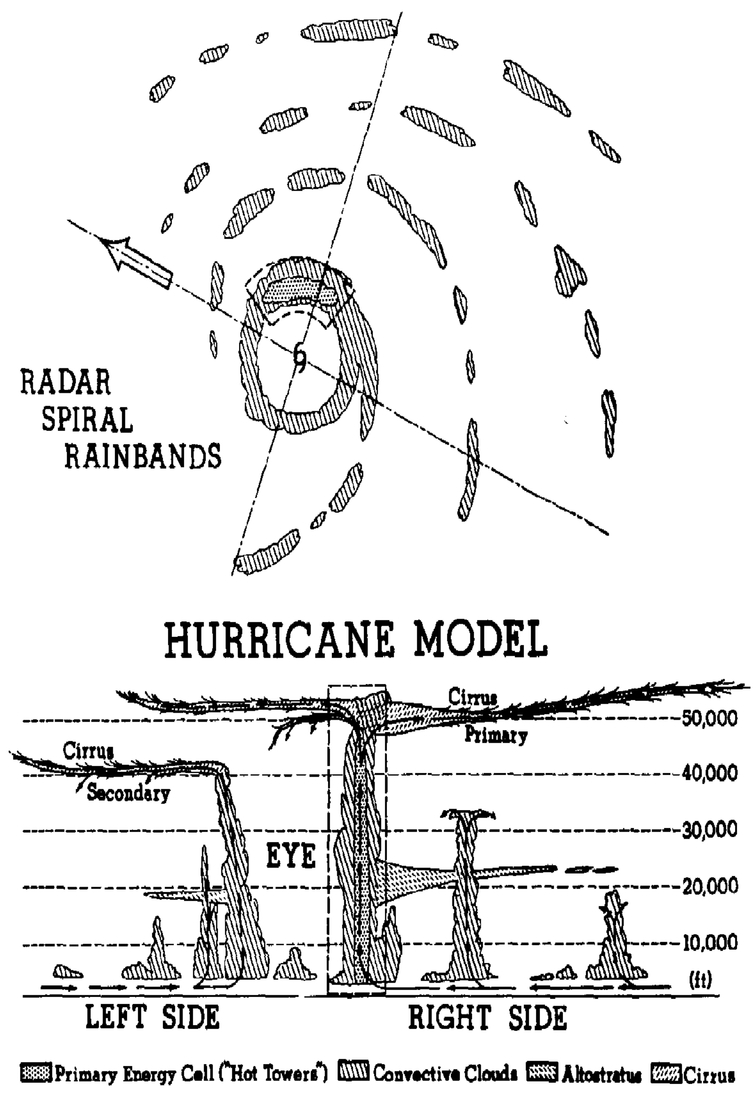
-Hurricane Carla, September 7-12, 1961. High water mark chart for Texas. Shaded area indicates the extent of flooding. (Based on data obtained from the Galveston District of the U.S. Army Corps of Engineers.)

FIGURE 5



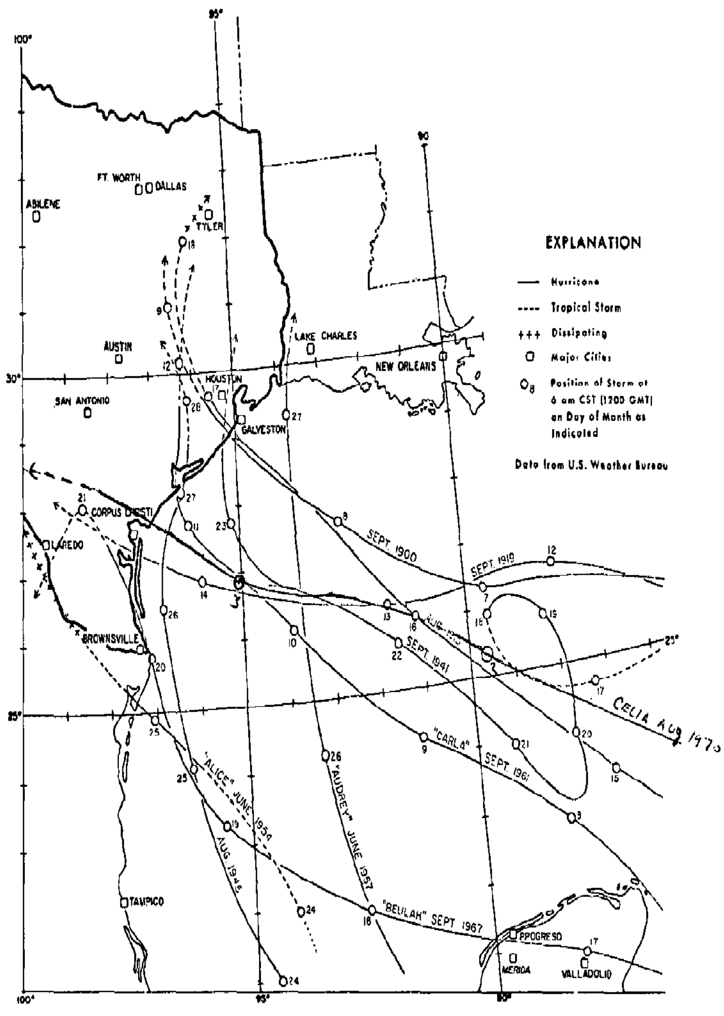
Gulf Coast *Zone* Subdivisions *Showing* Total
Hurricane Occurrences 1900-1956

FIGURE 6



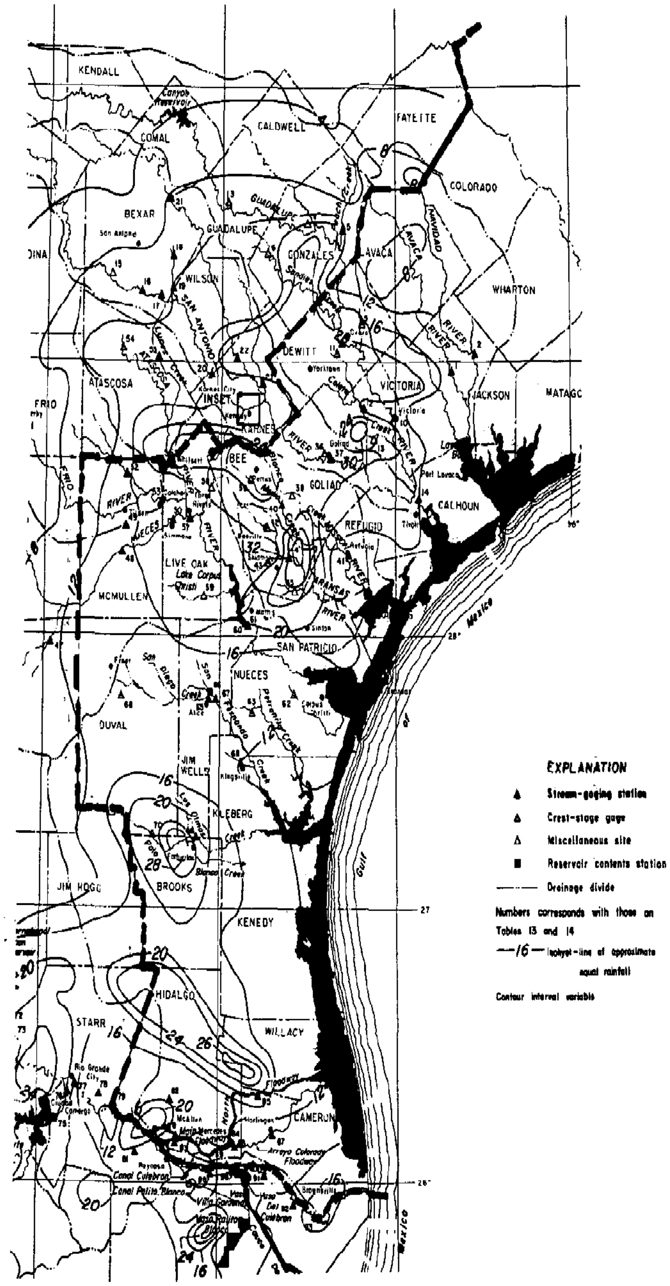
- The Hurricane Model. The primary energy cell (convective chimney) is located in the area enclosed by the broken line. (From NHRP Rept. no. 60, Hurricane Esther 1961.)

FIGURE 7



MAJOR HURRICANES
1900-1970

FIGURE 8



RAINFALL RESULTING FROM HURRICANE BEULAH

FIGURE 9

LAND-USE PATTERNS IN THE TEXAS COASTAL ZONE

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OFFICE OF THE GOVERNOR

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LAND-USE PATTERNS, TEXAS COASTAL ZONE

I. INTRODUCTION

The interface of the sea and the land, inherent in a coastal zone, prescribes a variety of land-use patterns. Variations in *relief* (from low coastal marshes and river swamps to upland prairies), in *climate* (from temperate-humid along the upper coast to semi-arid-subtropical in the lower coastal zone), in *soil fertility* (from fertile organic clays to barren sand), and in original *vegetation* (woodlands, prairies, and marshes) are natural features superimposed on the variety of land-use patterns attendant on population and industrial concentration. Further, in the dynamic and diverse environments of the Coastal Zone, the effects of man's use of land and water on natural systems is drawn sharply into focus. The result of these several factors is a complex pattern of land, water, and submerged-land use. Detailed analyses of the several land uses of the Texas Coastal Zone are beyond the scope of this report. Data have been derived from a series of extensive Coastal Zone maps currently in preparation by the Bureau of Economic Geology; at present, these are only partially completed.[1] The categories shown on the accompanying map (Plate I) and the statistical delineation in Table I have been generalized and derived from several of these more detailed maps.[2] Principal general-use categories shown on Plate I include Agriculture (crops), Range-Ranchland (cattle grazing), Woodland-Timber, Marsh (chiefly range and wildlife), Swamp (primarily wildlife), Recreation, Spoil, Made Land, Formal Wildlife Refuges, and No Principal Use Pattern. Industrial, urban, and other cultural features are shown on the Army Map Service topographic base (scale 1:250,000). These features were adapted for use in Table I from detailed maps of the Bureau's Environmental Geologic Atlas Series. Several

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[1]Anticipated completion date is the late spring of 1971.

[2]Component maps of the Bureau of Economic Geology Environmental Geologic Atlas of the Texas Coastal Zone, currently in preparation, include (1) geologic-landform map, (2) engineering-properties map, (3) topographic map, (4) active physical-properties map, (5) land-use map, (6) mineral and energy resource map, (7) vegetation and animal distribution map, (8) man-made features map, (9) climatic map, and (10) major depositional systems map. An index and map are provided in Attachment A.

categories pertinent to land use and land-use patterns, partially shown on Plate I, are given in the statistical summary of Table I. These include

1. total area: includes both land and water; data for five counties are partial, covering only that portion of the the county shown on the accompanying map:

2. agricultural lands;

3. range-ranchland;

4. woodland-timber areas;

5. marshland-swamp (wetlands) areas;

6. bays (surface-water area);

7. urban-industrial-residential areas;

8. natural fresh-water bodies (surface-water area);

9. artificial reservoirs (surface-water area);

10. recreational lands (primarily public beaches);

11. made lands (reclaimed);

12. formal wildlife refuges;

13. no existing use (principally wildlife);

14. subaerial spoil mounds and spoil wash;

15. hurricane flood areas (areas of inundation by Hurricanes Beulah and Carla);

16. bay-shore line;

17. open ocean-gulf shoreline;

18. total marine shoreline;

19. major drainage and irrigation canals;

20. major transportation canals.

II. SPECIFIC USE PATTERNS

Following are brief notes on the patterns and distribution of principal land and water uses of the Coastal Zone. These cover the 18-county area of the Coastal Zone with the exception of Harris, Jackson, Nueces, San Patirico, and Victoria Counties, which have not been completely surveyed.

AGRICULTURE - Agricultural use of land is extensive within the 18-county area of the Texas Coastal Zone, with approximately *41%* of the total land available in the area used for this purpose: approximately *5,120 square miles are presently under cultivation.* Concentration is on the original prairie grasslands of the central and upper Coastal Zone: agricultural use becomes less extensive in the South Texas Coastal Zone with the progressive decrease in rainfall. Total income from agricultural crops amounted to *$164 million in 1969,* with an additional value of *$25 million in U. S. Government payments,* combined to represent about *10%* of the total State income for these items.

Land is used principally for the cultivation of *rice,* with *60%* of the total production of Texas coming from the Coastal Zone. Main producing counties, north of the San Antonio River, include Brazoria, Chambers, Harris, Jackson, Jefferson, and Matagorda. Relatively high rainfall and extensive irrigation are main contributing factors.

A second important agricultural crop in the Coastal Zone is *grain sorghums,* accounting for about *12%* of the total State production. Principal yields are centered in the Corpus Christi area (Nueces and San Patricio Counties) and in the southernmost part of the Coastal Zone (Willacy and Cameron Counties).

Use of Coastal Zone land in the production of *cotton* is significant only in the Coastal Bend (Calhoun, Nueces, and San Patricio Counties) and in the lower Rio Grande Valley (Willacy County). Approximately *8%* of the total State production comes from the Coastal Zone.

Use of Coastal Zone land for production of *corn* and *hay* is relatively minor, resulting in less than 3% of the total State production. Concentration of these crops is in the central Coastal Zone (Matagorda, Brazoria, and Harris Counties), co-extensive with the area of principal beef production in the Coastal Zone. Grains such as oats and wheat are grown locally, but not in significant quantities.

With the exception of the subtropical lower Rio Grande Valley (Willacy and Cameron Counties), little land of the Coastal Zone is used in the production of *fruits* and *vegetables.* Other areas with at least limited production of these crops usually surround principal population centers.

RANGE-RANCHLAND - Approximately 42% (*4,425 square miles*) of the total area of the Coastal Zone is devoted to range and ranch sites; marshlands also used as range sites include an additional 760 square miles. Principal sites include the more arid region of South Texas, the low-lying coastal marshes, and the nonwooded barrier islands and levees of the central and upper Coastal Zone. The grazing of beef, the production of which accounts for nearly *10%* of the State total, is the principal use of the range land and is most significant in Brazoria, Harris, Jackson, Matagorda, and Victoria Counties. Cash receipts for livestock, mainly beef, from the Coastal Zone amounted to about *$83.5* million in 1969.

WOODLAND-TIMBER - Woodlands occur throughout the Coastal Zone of Texas but are most extensive in Orange County (a southern extension of the East Texas Piney Woodlands), in Brazoria and Matagorda Counties (along existing and ancestral drainage of the Colorado and Brazos Rivers), and in Kenedy County (including vegetated dunes of the South Texas sand sheet). Smaller areas of woodlands elsewhere in the Coastal Zone occur along streams, including low-swamp areas with water-tolerant vegetation, and on certain of the abandoned Pleistocene barrier island sands. Total woodland area in the Coastal Zone is approximately *1,600 square miles* (Table I and Plate I). Principal vegetation in the upper Coastal Zone woodlands includes *pine* and *mixed hardwoods;* in the central Coastal Zone, a variety of *water-tolerant hardwoods;* and in the southern Coastal Zone, chiefly *oak*. Commercial timbering is not significant in the Coastal Zone and is restricted primarily to Orange County. Some natural woodlands have been cleared for agricultural use in the Coastal Zone, but the total acreage for this purpose is small.

MARSHLANDS - Approximately *760 square miles* of the Texas Coastal Zone exist as marshlands or wetlands. These include dominantly low-lying coastal lands, the back sides of barrier islands, and low areas at the terminus of major river valleys and associated bayhead deltas. Salt marshes, brackish marshes, and fresh-water marshes (mapped separately in the Bureau of Economic Geology Environmental Geologic Atlas Series) are restricted to areas below the 4-feet above mean sea level. Grasses of varying tolerance to fresh and salt water are the sole vegetation. Most of the marshlands are used as ranch and range sites for the grazing of beef cattle, although the lowest parts of the marshlands, commonly with salt vegetation, are not overly suited for this prupose. Portions of some of the coastal marshes have been reclaimed, some by filling and others by draining. *Conflicting and detrimental uses of marshlands are considered in another section of this report.*

URBAN-INDUSTRIAL-RESIDENTIAL - General distribution of lands used in this category and their relationship with other uses of the land in the Coastal Zone are shown as a part of the Army Map Service base on the accompanying map (Plate I). Data given in Table I were derived from more detailed base maps. Specific breakdowns in this category are not given at the scale of the accompanying map but have been mapped in the Bureau of Economic Geology Environmental Geologic Atlas Series.

The principal urban and industrial concentration is in the upper part of the Coastal Zone. Highest concentrations are in Brazoria (Freeport area), Jefferson (Galveston area), Harris (Houston area), and Nueces (Corpus Christi area) Counties. Nearly *1,000 square miles* are included in this use category, based on the area covered in the accompanying map. This does not include all such land use in the 18-county Coastal Zone area; for example, only about 20% of the urban-industrial area of Harris County is included in Table I.

RECREATION - The area designated as recreational use, shown on the accompanying map (Plate I) and on Table I, includes primarily public beaches of the Coastal Zone. This amounts to a total area of about 23 square miles. Not included are a variety of public parks and other recreational areas, surface waters, and the National Seashore of Padre Island.

FORMAL WILDLIFE REFUGES - Five major National Wildlife Refuges have been designated in the Texas Coastal Zone: *Anahuac Refuge* in Chambers County (69 square miles); *two refuges* in Brazoria County (a total of 43 square miles); *Aransas Refuge* in Aransas County, with a *small area* extending into Refugio and Calhoun Counties (approximately 83 square miles); and *Laguna Atascosa Refuge* in Cameron County, with a small part extending into Willacy County (approximately 70 square miles). Total area formally designated as wildlife refuge is about *213 square miles*. In addition, wildlife use is coestensive with many of the other use categories.

BARREN LANDS - Barren lands, or land for which there is no existing use other than a limited use for wildlife, comprise nearly *580 square miles* in the Coastal Zone. Principal distribution of these lands is in the semiarid southern part of the Coastal Zone from Kleberg County south. Principally, these include extensive wind-tidal flats landward of Padre Island, as well as some of the active dune fields on the South Texas sand sheet. Smaller areas of wind-tidal flats exist on the back side of barriers in Calhoun and Aransas Counties. A small area of barren land exists in the coastal mudflats of Jefferson County, just south of Sabine Pass.

MADE LAND AND SPOIL - Made land, or land built up to higher levels by grading, represents about 34 square miles in the Coastal Zone. These occur principally in metropolitan areas along the coast: for example, the city of Galveston and most of Pelican Island are both on made land. The areas indicated as subaerial spoil on the accompanying table include only dredged sediment presently above sea level: *the category does not include the extensive areas of subaqueous spoil within the bays. Subaqueous spoil generally flanks dredged canals either as submarine mounds or as reworked spoil flats;* subaerial spoil is most extensive in areas where the Intercoastal Canal is cut into land. Some of the spoil areas have re-established vegetation; other areas are barren.

WATER - The extensive bays of the Coastal Zone comprise the principal surface-water bodies, covering approximately *2,100 square miles* and making up about *13%* of the total surveyed area of the Coastal Zone (Table I and Plate I). Principal bays and estuaries include Sabine Lake; Trinity-Galveston Bay, including East and West Bays; Matagorda Bay, including East Matagorda Bay; Espiritu Santo Bay; Lavaca Bay; San Antonio Bay; Aransas Bay, Copano Bay; Corpus Christi Bay; Baffin Bay; and Laguna Madre. *The bays of the Coastal Zone have extensive uses, many of which are conflicting* - commercial and sport fishing and oystering, recreation, shell dredging, and oil and gas production with their accompanying pipeline systems. Some of the conflicting uses of the bays are considered in another section of this report. Specific features of the mineral industry's uses of the bays are considered in the Task Area on Minerals and Mining.

Fresh-water bodies existing either as natural-water bodies or as artificial reservoirs comprise the other water areas of the Coastal Zone. The surface area of natural-water bodies in the Coastal Zone is about *1,700 square miles;* artificial reservoirs cover about *65 square miles* (Table I and Plate I).

HURRICANE FLOOD - Approximately *3,208 square miles* of the lower parts of the Texas Coastal Zone have been inundated by salt water from surges of Hurricanes Carla and Beulah during the past decade; particularly prone to flooding are the low coastal marshes and the lower reaches of the main river valleys. Coastal flood areas are not specified on the accompanying map (Plate I); statistical data reported in Table I are based on detailed maps of hurricane flooding prepared as a part of the Bureau of Economic Geology Environmental Geologic Atlas Series (available in the spring of 1971).

SHORELINE - Total shoreline in the Texas Coastal Zone amounts to slightly over *1,890 miles*. Of this total, *1,419 miles are bay shoreline* and *373 miles are open-ocean or gulf shoreline*. These figures are computed from detailed 715-minute topographic maps of the Coastal Zone, most of which were constructed during the past decade. The shoreline is a dynamic zone subject to constant change in the form of erosion or accretion: it is thus subject to change in total length. The main physical processes of the shoreline are considered in another section of this report.

CANALS - An extensive canal system has developed in the Texas Coastal Zone, including both *transportation canals* and *irrigation-drainage canals*. Major transportation canals amount to a total of *668 miles* within the surveyed part of the Coastal Zone (Plate I and Table I); this figure includes the portions of the transportation canals dredged within bays, as well as the land-cut parts of the canals. Approximately *3,120 miles of irrigation and drainage* canals have been cut in the Coastal Zone, mostly coestensive with agricultural lands.

III. PHYSICAL PROCESSES

Determining factors in land use are the degree, variety, and nature of physical processes. In the dynamic environments of the Coastal Zone, these factors assume prime importance. A distinct suite of processes affect the barrier islands, the bays, lagoons, and estuaries, and the mainland. Among the more important processes are those that *determine rates of erosion or accretion by either water or wind, extent and kind of flooding, and transportation and dispersal of sediments*. Following is a brief outline of the main physical processes existing in the Texas Coastal Zone, listed in terms of natural systems and their component environments.

A. *BARRIERS*

1. *Shoreface* (offshore, 0 to approximately 30 feet)
   a. *Normal sea conditions* - Onshore and lateral transport of sand by *bottom currents* (tidal and wind-generated waves). Some suspension material deposited on the lower shoreface and mixed with sand through organic activity.
   b. *Storm conditions* - Sand and shell are transported onshore as *large* sand waves. Sand and mud are carried offshore in suspension by turbidity currents and are deposited on parts of the shoreface.

2. *Foreshore and backshore*
   a. *Normal sea conditions* - Sand is spread in thin sheets on the foreshore by swash and backwash; some of this sand is transported by wind across the berm onto the backshore where it may accumulate as coppus mounds. Some areas of the backshore are deflated of sand, leaving a pavement of shell and shell debris.
   b. *Storm conditions* - Under storm conditions the foreshore is eroded and sand is deposited as a storm beach above normal high-tide mark. The beach is reworked by eolian processes.

3. *Foredune ridges*
   These ridges accrete under prevailing southeast-wind conditions; sand is derived from the backbeach area. Hurricane tracks passing over the barrier severely erode the foredunes. Vegetation is the main agent of dune stabilization; this may be severely affected by overgrazing. Salt-tolerant plants are the main stabilizers; therefore, exceptionally heavy rainfall may reduce the plant cover, resulting in dune activation.

4. *Beach-accretion ridges*
   These are affected by the same processes that operate on foredunes.

5. *Storm channels and washover fans*
Channels are scoured during storms; sand is transported by unidirectional currents toward the bay during storm-surge flood. Sand deposition occurs within the channels as bars and sheets that spread radially away from the distal parts of the channel. These bars form a coalescing sand body called a "washover fan." Some sediment returns seaward through storm channels during the ebb surge. Under normal sea conditions, the seaward part of the channel is sealed with sand that is swept along shore and into the channel mouth by longshore drift; this sediment is then transported bayward with the next storm. Once established, storm channels are avenues of high-velocity storm currents.

6. *Blowouts and dunes*
Foredune ridges and beach accretion ridges, when barren of vegetation, are eroded by the wind. Sections of foredunes or beach-accretion ridges may be breached when vegetation is removed by fires, overgrazing, etc.. Intense local scour by the wind is termed a "blowout." Downwind from blowouts sand migrates as dunes; dunes will continue to migrate downwind until stabilized by vegetation or until they meet with a body of water. Likewise, blowouts will remain active until the breach is vegetated.

7. *Vegetated barrier flats*
Sediment accumulation here is chiefly fine sand blown into the area from beach and foredune areas by the prevailing southeast wind. Biologic activity here consists of root-mottling and burrowing by rodents and crustaceans.

8. *Wind-tidal flats*
Wide, barren areas lying between the vegetated barrier flats and the coastal bays receive much of their sediment from the bay. Generally during periods of strong north wind, these flats are inundated and fine sand is moved across the flats by wind-generated currents. Suspension material settles across the flats as the water recedes following cessation of the wind. These flats also receive some sand and mud brought into the area at time of storms; at other times, under normal bay-level conditions, wind-transported sand derived from barriers accumulates here. These are areas of great variation in intensity of physical conditions: temperature fluctuation is extreme, and chemical properties of surface and interstitial water is quite variable.

B. *TIDAL CHANNELS*

1. *Main channel*
Main channels are the primary lines of communication between the Gulf and the bays. Tidal range along the Gulf of Mexico is low (1.5-2.0 feet), and tidal currents are of relatively low velocity. Strong, persistent winds either offshore or onshore sometimes increase flow through tidal channels. During flood tide, the highest velocity is attained on the seaward side of the channel; during ebb tide, on the bayward side. Direction of flow through channels reverses itself twice daily with the tides. Deposition occurs at the bayward and seaward ends of channels by vertical accretion and along the channel banks. On the Texas Coast, lateral accretion is along the east bank. Holes are scoured in the channel at points of current convergence on the Gulf side and the bay side during flood and ebb tides, respectively.

2. *Flood delta*
Flood deltas, on the bay side of tidal channels, are constructed of sediment largely derived offshore. Jet flow develops at the distal end of the main channel; here, as the flow spreads radially, distributary channels form, and sediment accumulates as sand and mud shoals. Shoals may become emergent, creating new land, with the subaerial part of the delta developing into marshes, beach ridges, etc., that are affected by the same processes that act on similar features on the barriers. This type of land creation is especially significant at the mouth of the Brazos River.

3. *Ebb delta*
Sediment from which the ebb delta is constructed is also derived offshore. The process of deposition is the same as on the flood delta - by a decrease in velocity as the jet moves downcurrent from the channel mouth. Higher physical energy (wind-generated currents, primarily) in the Gulf waters than in the bays redistributes much of the ebb-delta sediment and prevents emergence of these features.

C. *BAYS AND LAGOONS*

1. *Bay perimeter* - areas not permanently inundated.
Marsh, beach, and tidal-flat environments comprise the bay area above sea level. Processes on marshes and beaches are generally the same everywhere; however, beaches along bay margins are less well developed than those on the seaward side of barriers because of a lower physical-energy expenditure along bay margins.

Beaches within bays are not affected by astronomical tides; beach construction is by wind-generated waves. Material from which beaches are constructed consists of shell derived from barriers along the seaward-bay margin and of either river-borne sand or sand derived locally by undercutting of the Pleistocene.

2. *Shoal, marginal deposits*
   In the larger bays, sand shoals occur along both the mainland and barrier shoreline. Sand source is fluvial (along mainland shore), from Pleistocene barrier islands, and from the back side of modern barriers. Distribution is by longshore drift; breaker bars are associated with unvegetated sandflats, particularly in either areas that front the prevailing southeast winds or areas that face into the tract of polar-air masses. Processes here are analogous to those operating on the upper shoreface of barrier islands; however, physical energy is less intense and biological activity relatively greater than along the barrier shoreface. Where bottom drift of sand is less vigorous, marine grasses become established; these plants retard the movement of the traction load and provide an energy baffle that allows deposition of suspension load (muds).

3. *Mud-settling basin*
   Suspension-load material is derived from rivers, from the Gulf, and from undercutting of Pleistocene deposits along the mainland shore. Mud is supplied to bays from the Gulf through storm channels and tidal channels during storm-surge flood. Mud is the dominant sediment in most bays where water depth is 6 feet or more. Under normal bay conditions, transport of sand along the bay floor occurs in water less than 6 feet deep.

4. *Oyster reef*
   Sedimentation within bays is affected by the larger, laterally extensive oyster reefs. Reefs cause an increase in current velocity by decreasing water depth immediately upcurrent and across the reef crest. As flow passes beyond the reef crest, velocity again decreases and pseudo-feces and suspension sediment are deposited. Oysters themselves build up the bay floor by shell accumulation.

D. *BAYHEAD AND ESTUARINE DELTAS*

These depositional features are the product of the interplay between fluvial and marine processes. Traction and suspension load travel together through the fluvial system to the mouth of distributaries. Beyond the mouth, traction and suspension load are segregated; traction load (sand) is dropped near the distributary mouth as current velocity decreases abruptly. Suspension load (mud) is carried out into the bay, where it accumulates as prodelta muds. Most bayhead deltas front the prevailing onshore wind, which drifts fine sediment into interdistributary and marsh areas. Coarser material, sand, from the delta front is spread laterally and onshore by wind-generated waves to form relatively widespread sand sheets and beaches. Delta surfaces are built up from fine grained sediment (predominantly silt and mud) transported to the area through crevasse splays, from overbanking from distributaries, and from mud brought in from bays and deposited by wind tides. Much of the traction load accumulates in distributaries at about the point where the fluvial system begins to become shallow and to break up into numerous channels. Marshes, lakes, and swamps are integral parts of deltas; these receive mostly fine sediment from suspension. Water in the lakes and marshes ranges from fresh to normally saline.

E. *MARSHES*

Areas permanently inundated by a few inches of water or frequently flooded by astronomical tides are the habitat of salt-tolerant plants. Marshes occur on barriers and along mainland shorelines. Vegetation of these coastal marshes displays zonation with elevation, and the salt marshes are divided into low and high marsh. The low marsh is dominated by _Spartina alterniflora_, which grows in a few to several inches of water and can be seen forming a narrow vegetated band along the bays and tidal creeks. Where marginal areas are very shallow, _Spartina alterniflora_ forms extensive marshlands. Landward, the low marsh grades into succulent plants (_e.g._, _Batis_, _Salicornia_, and _Suaeda_) and finally into _Borrichia_ and _Spartina spartinae_.

Physical processes range from the minimal to the intense. Marsh sediment is disturbed by plant roots and burrowing animals (crustaceans and worms). Sediment deposited in marsh areas is transported into the area by a variety of processes and is derived from several sources. On mainland sides of bays, sediment deposited in marshes is fluvially derived and is deposited by means of crevasse splays, overbanking, and wind tides. Sediments of marshes associated with barriers are deposited by wind tides, eolian processes, and hurricane washovers. Coastal marshes are areas of intense biological activity and extremes in physical processes. Fluctuations exist in temperature, in aridity, and in soil salinity. Because of their vegetation, marshes are very resistant to erosion, even when subjected to storm-generated currents and breaking waves.

F. *FLUVIAL SYSTEMS*

Most fluvial systems along the Texas Coastal Plain are of the fine-grained meander-belt type, e.g., Trinity, Brazos, and Nueces. The Colorado is a coarse-grained meander-belt type, and the San Bernard is locally braided. These stream types result from their particular types of discharge. Braided streams have very short-duration peak discharge, and fine-grained meander-belt streams have relatively long-duration peak discharge.

Most of the coarser grained sediment of meandering streams is deposited as lateral accretionary features - point bars - adjacent to the convex bank. Levees are constructed of both traction- and suspension-load material that is deposited along the channel banks at times when the stream overflows the channel; relatively coarse material is carried beyond the levee when crevasses are scoured through them. These deposits are the fan-shaped "crevasse splays." Beyond the levees, suspension load accumulates in the flood basin; flood waters move very sluggishly and finally stagnate. The flood plain is underlain by point-bar, levee, and flood-basin deposits. The flood plain is characterized by abandoned channel segments and meander cut-offs that are later filled with overbank sediment. These inactive channel segments show varying degrees of sediment fill and occur as linear or oxbow lakes, swamps, marshes, or depressions filled with mud. Swamps and marshes are best developed on flood plains near channel mouths.

G. *EOLIAN SYSTEMS*

Sand transport is generally toward the northwest under the driving force of the prevailing southeast winds. Dunes commonly develop downwind from devegetated older dunes. Blowouts result from devegetation of older dunes; this vegetation is killed or physically removed by overgrazing, fires, or storms. In this area, the wind is able to remove sand down to the water table. This sand moves downwind from the blowouts as parabolic or sief dunes. Sief dunes have crests modified by northers, but these north winds are not of sufficient duration to alter dune shape significantly or to transport a large volume of sand to the southeast. Dunes are ultimately stabilized by a vegetal cover of grass, mesquite, chaparral, some cacti, and, in some instances, live oaks.

Conditions which favor construction of an eolian plain such as that in South Texas are (1) a local sand source and (2) arid to semiarid climate. Sand here is derived from underlying abandoned deltaic-plain and meander belts. Winds blow from the southeast 9 months each year; average annual rainfall is generally fewer than 20 inches.

IV. EFFECTS OF MAN'S ACTIVITY ON COASTAL ENVIRONMENTS

The numerous uses of Coastal Zone lands and waters by man result in some use patterns *essentially in harmony with natural processes* and in others that *severely jeopardize the natural balance*: certain uses are in *sharp conflict with other uses*, especially within the Coastal Zone bays. Proper land and water uses will come only from a greater understanding of the natural processes at work in the area and of their relation to man's activity.

The purpose of this section is to outline some of man's activity and its relation to the natural environments and processes of the Coastal Zone.

CHANNELIZATION AND DREDGING - To date, the Coastal Zone bays have been the site of extensive dredging and channelization, involving the construction of *transportation canals, access canals* for specific bay operations, and *shell dredging*. All these activities are deemed a necessary part of the existing Coastal Zone industries, yet they affect the natural bay system significantly. Spoil dredged from canals and piled along the margins of the canals tends to compartmentalize the shallow bays and restrict circulation. *Reworking of dredged spoil* by waves and currents provides the principal supply of sediment to the bays. In many areas, *marginal grass flats - vital components in the bay ecosystem - are being blanketed by reworked spoil*, converting grass flats to barren sand areas.

Another type of channelization, construction of *artificial passes* between bays and the Gulf, affects the natural bay systems. Every pass cut through the barrier islands decreases the tidal surge through the existing passes. Most of the bays of the Texas Coastal Zone can naturally maintain only one pass per bay; artificial channels have to be maintained by continual dredging. In addition, passes, whether natural or artificial, receive the main tidal surges during storms. Additional passes make the barriers and the protected bay *more vulnerable to storm destruction*.

DEVEGETATION - The *importance of vegetation in land stabilization* is obvious when considering the changes in natural landforms along the present Texas Coast. The upper Coastal Zone is in a humid climate with mostly vegetated landforms; the southern part of the Coastal Zone is subtropical, with relatively low rainfall and fewer vegetated landforms. This dryness in large measure accounts for the extensive inland dune fields and the active dunes on the barrier islands of South Texas, as well as the extensive wind-tidal flats of Laguna Madre. The devegetation of natural landforms, whether a consequence of development, overgrazing, waste disposal, or marsh burning, *exposes bare sediment to erosion* by storm and by normal waves and currents and significantly reduces the stability of the land. Vegetated barrier islands afford the *best natural protection* from hurricanes and storms. Devegetation in *landside-drainage* systems greatly increases the sediment load of streams, resulting in increased infilling of the bays into which the streams discharge. For example, the natural and artificial drainage system of Gum Hollow, a small stream emptying into Nueces Bay, delivered *270,000 cubic yards* of sediment into the bay during the heavy rainfall accompanying Hurricane Beulah. This resulted chiefly because stabilizing vegetation in the stream was killed by brine discharge from petroleum production operations.

LAND RECLAMATION - Artificial filling of bays and marshlands provides valuable *shorefront development land* or room for industrial expansion, *but it also provides sediment* for hurricane erosion and redistribution, *impedes effective bay circulation,* and locally *reduces bay area,* causing additional flooding elsewhere during high water.

COASTAL CONSTRUCTION - Construction of numerous groins, piers, jetties, and platforms has modified circulation patterns within many bays and estuaries. Erosion and deposition within the natural system is *upset,* and entire baylines may become *unbalanced,* resulting in *choking deposition* in some areas and *damaging erosion* in other shoreline stretches. Necessary coastal construction should be *planned to minimize alteration of natural circulation,* thus preventing unmanaged shoreline changes.

Several factors should be considered when planning coastal structures designed to *prevent destruction of property by hurricanes.* Barrier islands are *natural barriers* to much of the surge effect of storms. Some of the storm's energy passes through natural passes in the barriers to flush bays and naturally dredge tidal channels. Because some hurricanes are of such great magnitude, breaching in the form of washover channels permits additional amounts of the storm surge to reach bays. Isolating back-bay areas by man-made structures may *adversely affect flushing* of these water bodies, a very critical process, since man has already restricted the volume of streams entering the bays by construction of upstream dams. Reduction of natural flushing processes would *increase and emphasize the effects of pollution of the bay waters.*

WASTE DISPOSAL - Most of the problems of waste disposal associated with large industrial and metropolitan areas have been well publicized. *An area usually not emphasized is the disposal of waste through subsurface media.* Areas of permeable substrates should be avoided as sites of disposal, since these permeable materials directly connect with the ground-water system. Construction of septic tanks in loose and permeable spoil should also be avoided. Abandoned sand pits may make readily available sites for waste disposal from an immediate economic point of view, but they are the worst possible sites form the standpoint of protecting groundwater supplies. Extensive areas of the Coastal Zone are underlain by tight impermeable clays which are ideal waste-disposal sites. Unfortunately, these clays support the more fertile soils of the coastal area.

MINERAL EXTRACTION - The bays and estuaries of the Texas Coastal Zone are the sites of numerous *oil and gas fields;* they are also sites for the *dredging of shell*. Both of these operations are potential sources of pollution if production operations are not carefully managed.

TABLE I

USE	ARANSAS	BRAZORIA	CALHOUN	CAMERON	CHAMBERS	GALVESTON
Total Area[1]	464.0	1520.0	960.0	1200.0	896.0	696.0
Total Land Area[2]	281.0 - *61.0*	1443.0 - *95.0*	536.0 - *56.0*	1082.0 - *90.0*	625.0 - *70.0*	431.0 - *62.0*
Total H_2O Area[2]	183.0 - *39.0*	77.0 - *5.0*	424.0 - *44.0*	118.0 - *10.0*	271.0 - *30.0*	265.0 - *38.0*
LAND AREAS						
Agriculture[3]	21.0 - *7.5*	620.0 - *43.0*	117.0 - *21.8*	704.0 - *65.1*	345.0 - *55.2*	246.0 - *57.1*
Range-Ranch[3]	132.0 - *47.0*	84.0 - *5.8*	262.0 - *48.9*	132.0 - *12.2*	51.0 - *8.2*	40.0 - *9.3*
Woodland-Timber[3]	--- ---	502.0 - *34.8*	42.0 - *7.8*	--- ---	70.0 - *11.2*	16.0 - *3.7*
Marsh-Swamp[3]	22.0 - *7.8*	56.0 - *3.9*	75.0 - *14.0*	0.1 - *0.0*	101.0 - *16.2*	55.0 - *12.8*
Urban Industrial-Residential[3]	10.0 - *3.6*	128.0 - *8.9*	18.0 - *3.4*	7.1 - *6.6*	37.0 - *5.9*	58.0 - *13.5*
Recreational[3]	1.2 - *0.4*	1.8 - *0.1*	2.3 - *0.4*	1.7 - *0.2*	0.1 - *0.0*	3.2 - *0.7*
Subaerial Spoil[3]	1.6 - *0.6*	4.8 - *0.3*	8.0 - *1.5*	8.2 - *0.8*	2.5 - *0.4*	8.3 - *1.9*
Made Land[3]	--- ---	3.2 - *0.2*	--- ---	--- ---	--- ---	3.9 - *0.9*
Wildlife Refuge[3]	77.0 - *27.4*	43.0 - *3.0*	4.0 - *0.7*	69.0 - *6.4*	18.0 - *2.9*	--- ---
Barren Land[3]	16.0 - *5.6*	--- ---	8.0 - *1.5*	96.0 - *8.9*	--- ---	1.0 - *0.2*
WATER AREAS						
Bays[2]	179.0 - *38.6*	42.0 - *2.8*	404.8 - *42.2*	92.0 - *7.7*	243.0 - *27.1*	257.0 - *36.9*
Artificial Reservoirs[1]	---	16.0	---	10.0	4.4	1.2
Natural Fresh Water Bodies[1]	4.2	19.2	18.9	16.0	24.0	6.4
OTHER FEATURES						
Bay Shoreline[4]	140.0	54.0	286.0	96.0	63.0	120.0
Open Ocean Shoreline[4]	20.0	30.0	38.0	32.0	1.0	50.0
Total Shoreline[4]	160.0	84.0	324.0	128.0	64.0	170.0
Drainage Channels[4]	3.0	372.0	100.0	≈730.0	280.0	85.0
Transportation Canals[4]	29.0	68.0	52.0	32.0	44.0	76.0
Hurricane Flood Areas[2]	135.0 - *48.4*	422.0 - *29.2*	371.0 - *69.2*	120.0 - *11.1*	283.0 - *45.3*	257.0 - *59.6*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

TABLE I (Continued)

USE	HARRIS	JACKSON	JEFFERSON	KENEDY	KLEBERG	MATAGORDA
Total Area[1]	544.0	576.0	1024.0	1824.0	960.0	1408.0
Total Land Area[2]	522.0 - *96.0*	572.0 - *99.0*	946.0 - *92.0*	1757.0 - *96.0*	812.0 - *85.0*	1157.0 - *82.0*
Total H_2O Area[2]	22.0 - *4.0*	4.0 - *1.0*	78.0 - *8.0*	67.0 - *4.0*	148.0 - *15.0*	251.0 - *18.0*
LAND AREAS						
Agriculture[3]	285.0 - *54.6*	250.0 - *43.7*	442.0 - *46.7*	--- ---	32.0 - *3.9*	593.0 - *51.3*
Range-Ranch[3]	--- ---	257.0 - *44.9*	24.0 - *2.5*	1186.0 - *67.5*	704.0 - *86.7*	180.0 - *15.6*
Woodland-Timber[3]	56.0 - *10.7*	42.0 - *7.3*	81.0 - *8.6*	245.0 - *13.9*	24.0 - *3.0*	245.0 - *21.1*
Marsh-Swamp[3]	16.0 - *3.1*	13.0 - *2.3*	220.0 - *23.3*	--- ---	2.4 - *0.3*	87.0 - *7.5*
Urban Industrial-Residential[3]	160.0 - *30.6*	10.0 - *1.7*	168.0 - *17.8*	0.5 - *0.0*	12.0 - *1.5*	37.0 - *3.2*
Recreational[3]	--- ---	--- ---	2.0 - *0.2*	3.3 - *0.2*	1.4 - *0.2*	3.6 - *0.3*
Subaerial Spoil[3]	4.8 - *0.9*	--- ---	1.3 - *0.1*	18.0 - *1.0*	4.8 - *0.6*	11.0 - *1.0*
Made Land[3]	--- ---	--- ---	6.1 - *0.6*	--- ---	--- ---	--- ---
Wildlife Refuge[3]	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
Barren Land[3]	--- ---	--- ---	1.6 - *0.2*	304.0 - *17.3*	31.0 - *3.8*	0.8 - *0.1*
WATER AREAS						
Bays[2]	15.2 - *2.8*	--- ---	32.0 - *3.1*	64.0 - *3.5*	128.0 - *13.3*	242.2 - *17.2*
Artificial Reservoirs[1]	3.0	---	24.0	---	---	---
Natural Fresh Water Bodies[1]	4.0	4.0	22.0	3.2	20.4	8.4
OTHER FEATURES						
Bay Shoreline[4]	40.0	---	17.0	126.0	144.0	129.0
Open Ocean Shoreline[4]	---	---	33.5	50.0	23.0	62.0
Total Shoreline[4]	40.0	---	50.5	176.0	167.0	191.0
Drainage Channels[4]	115.0	154.0	320.0	---	1.0	340.0
Transportation Canals[4]	26.0	---	80.0	54.0	23.0	58.0
Hurricane Flood Areas[2]	54.0 - *10.3*	78.0 - *13.6*	468.0 - *49.5*	160.0 - *9.1*	90.0 - *11.1*	464.0 - *40.1*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

T A B L E I (Continued)

USE	NUECES	ORANGE	REFUGIO	SAN PATRICIO	VICTORIA	WILLACY
Total Area[1]	1024.0	392.0	832.0	600.0	440.0	768.0
Total Land Area[2]	739.0 - *72.0*	378.0 - *96.0*	792.0 - *95.0*	590.0 - *98.0*	438.0 - *100.0*	717.0 - *93.0*
Total H_2O Area[2]	285.0 - *28.0*	14.0 - *4.0*	40.0 - *5.0*	10.0 - *2.0*	2.0 - *0.0*	51.0 - *7.0*
LAND AREAS						
Agriculture[3]	450.0 - *60.9*	77.0 - *20.4*	117.0 - *14.8*	363.0 - *61.5*	119.0 - *27.1*	336.0 - *46.9*
Range-Ranch[3]	86.0 - *11.6*	--- ---	640.0 - *80.8*	166.0 - *28.1*	240.0 - *54.8*	241.0 - *33.6*
Woodland-Timber[3]	22.0 - *3.0*	159.0 - *42.1*	11.2 - *1.4*	12.8 - *2.2*	73.0 - *16.7*	8.0 - *1.1*
Marsh-Swamp[3]	14.4 - *1.9*	71.0 - *18.8*	68.0 - *0.9*	19.0 - *3.2*	3.2 - *0.7*	0.8 - *0.1*
Urban Industrial-Residential[3]	138.0 - *18.7*	69.0 - *18.3*	15.0 - *1.9*	28.0 - *4.7*	3.2 - *0.7*	7.0 - *1.0*
Recreational[3]	1.9 - *0.3*	--- ---	--- ---	--- ---	--- ---	0.8 - *0.1*
Subaerial Spoil[3]	8.0 - *1.1*	16.0 - *0.4*	--- ---	--- ---	--- ---	1.8 - *0.3*
Made Land[3]	19.0 - *2.6*	--- ---	--- ---	1.6 - *0.3*	--- ---	--- ---
Wildlife Refuge[3]	--- ---	--- ---	1.6 - *0.2*	--- ---	--- ---	0.8 - *0.1*
Barren Land[3]	--- ---	--- ---	--- ---	--- ---	--- ---	121.0 - *16.9*
WATER AREAS						
Bays[2]	282.0 - *27.5*	12.5 - *3.2*	33.6 - *4.0*	6.0 - *1.0*	--- ---	42.0 - *5.5*
Artificial Reservoirs[1]	1.3	1.9	---	1.5	1.0	0.4
Natural Fresh Water Bodies[1]	1.4	---	6.8	2.1	0.6	8.4
OTHER FEATURES						
Bay Shoreline[4]	80.0	9.3	32.0	47.0	---	36.0
Open Ocean Shoreline[4]	21.0	---	---	---	---	12.6
Total Shoreline[4]	101.0	9.3	32.0	47.0	---	48.6
Drainage Channels[4]	133.0	154.0	70.0	83.0	80.0	100.0
Transportation Canals[4]	72.0	39.0	---	---	---	15.0
Hurricane Flood Areas[2]	88.0 - *11.9*	94.0 - *24.8*	42.0 - *5.3*	40.0 - *6.7*	24.0 - *5.4*	18.0 - *2.5*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

T A B L E I (Continued)

USE	TOTALS
Total Area[1]	16128.0
Total Land Area[2]	13818.0 - *86.0*
Total H_2O Area[2]	2310.0 - *14.0*
LAND AREAS	
Agriculture[3]	5117.0 - *37.0*
Range-Ranch[3]	4425.0 - *32.0*
Woodland-Timber[3]	1609.0 - *11.6*
Marsh-Swamp[3]	762.7 - *5.5*
Urban Industrial-Residential[3]	969.7 - *7.0*
Recreational[3]	23.3 - *0.2*
Subaerial Spoil[3]	84.7 - *0.6*
Made Land[3]	33.8 - *0.2*
Wildlife Refuge[3]	213.4 - *1.5*
Barren Land[3]	579.4 - *4.2*
WATER AREAS	
Bays[2]	2075.3 - *12.9*
Artificial Reservoirs[1]	
Natural Fresh Water Bodies[1]	
OTHER FEATURES	
Bay Shoreline[4]	
Open Ocean Shoreline[4]	
Total Shoreline[4]	
Drainage Channels[4]	
Transportation Canals[4]	
Hurricane Flood Areas[2]	3208.0 - *23.3*

[1]measured in square miles

[2]measured in both square miles (gothic print) and % of total area (italics)

[3]measured in both square miles (gothic print) and % of total land area (italics)

[4]measured in linear miles

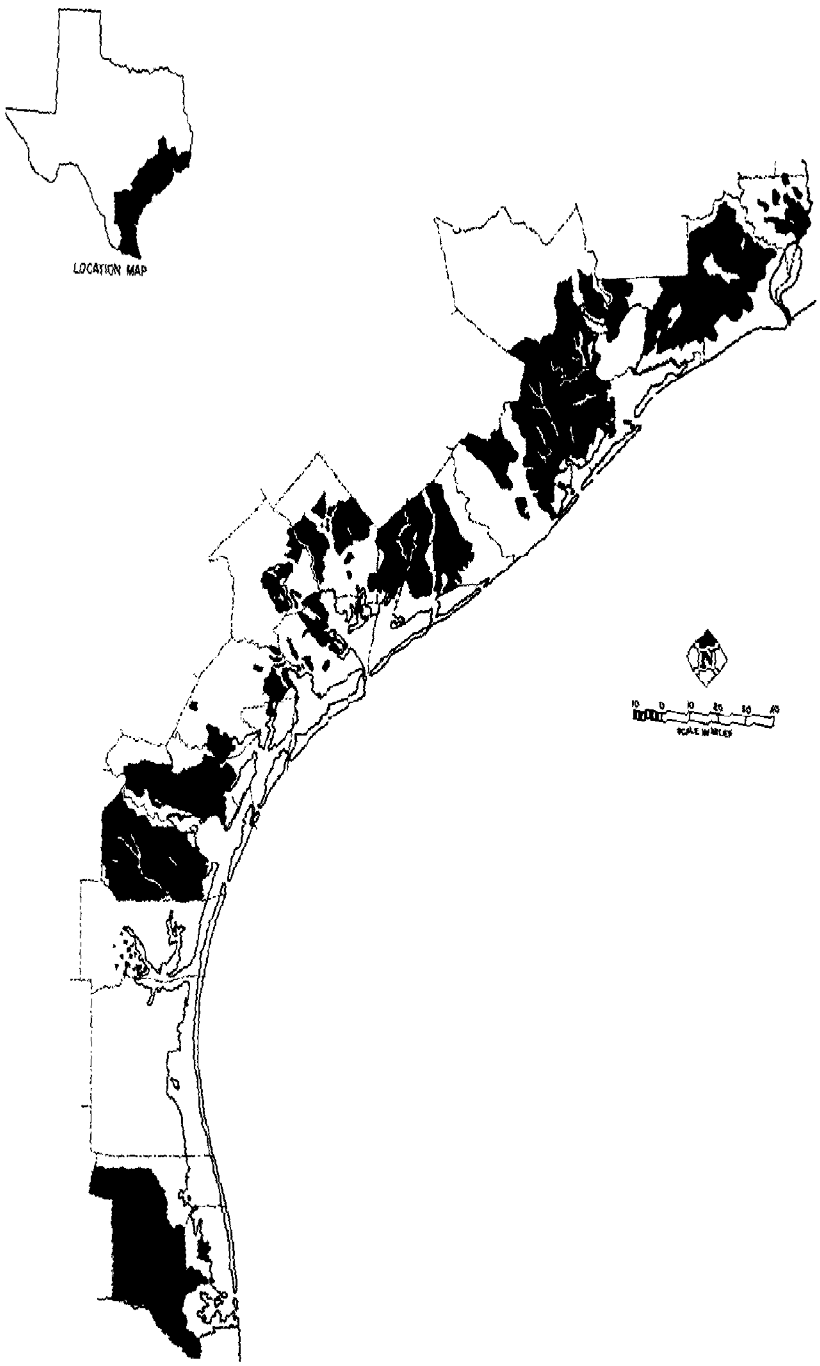

PLATE 1-A.

AGRICULTURE: CULTIVATED LANDS

IN THE COASTAL ZONE

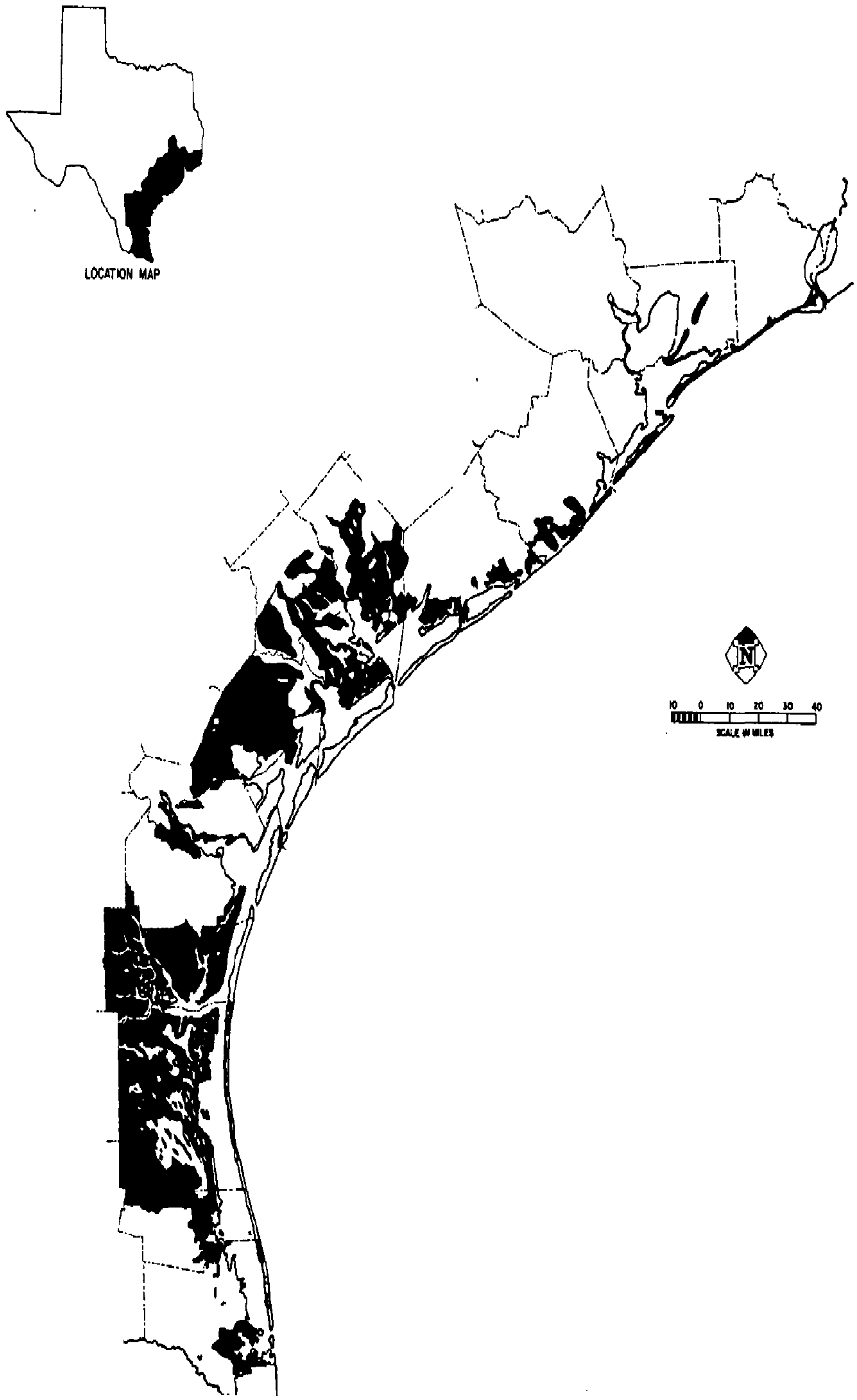

PLATE I-B.

RANGE - RANCHLAND IN THE COASTAL ZONE

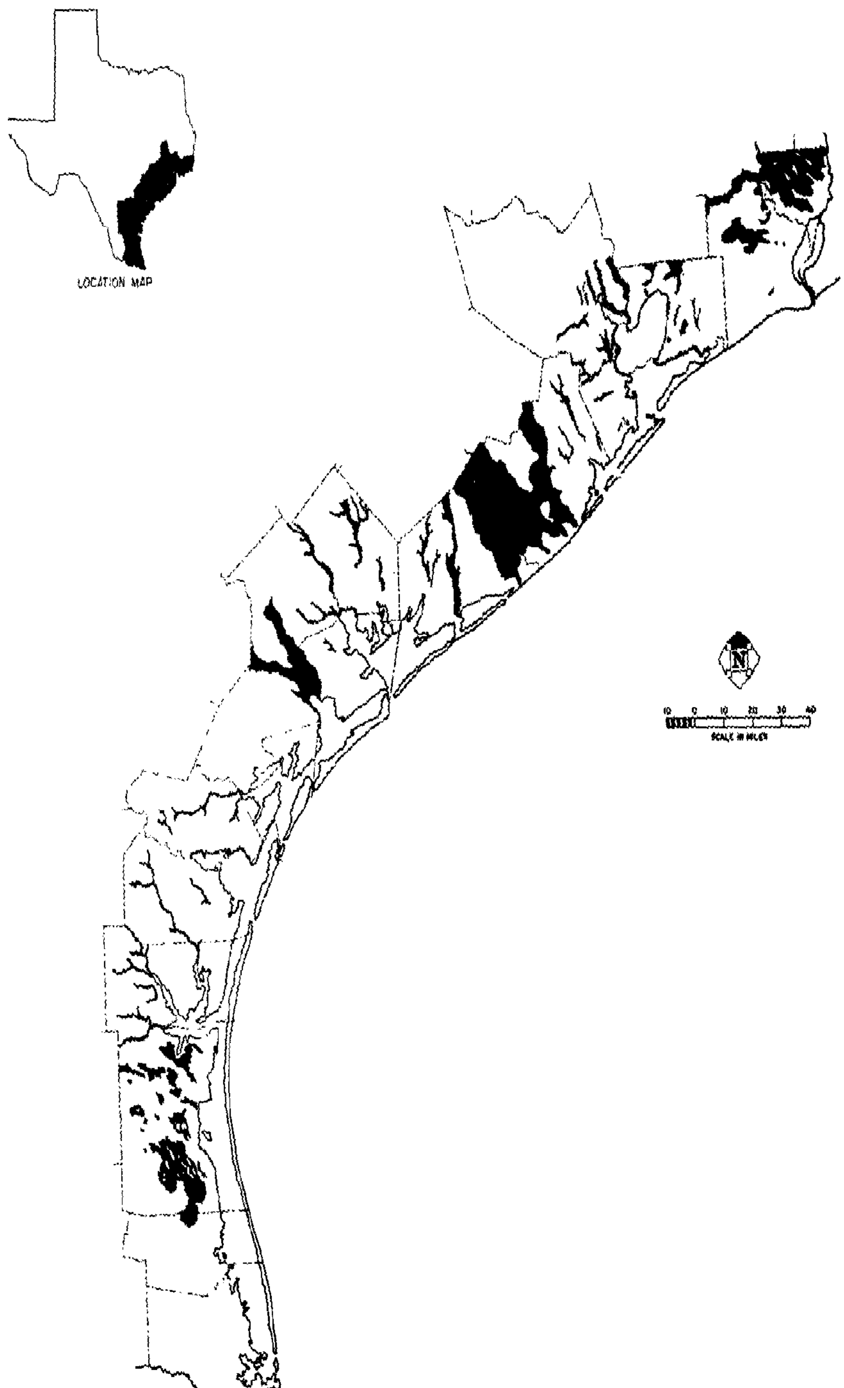

PLATE I-C.

TIMBER - WOODLANDS IN THE COASTAL ZONE

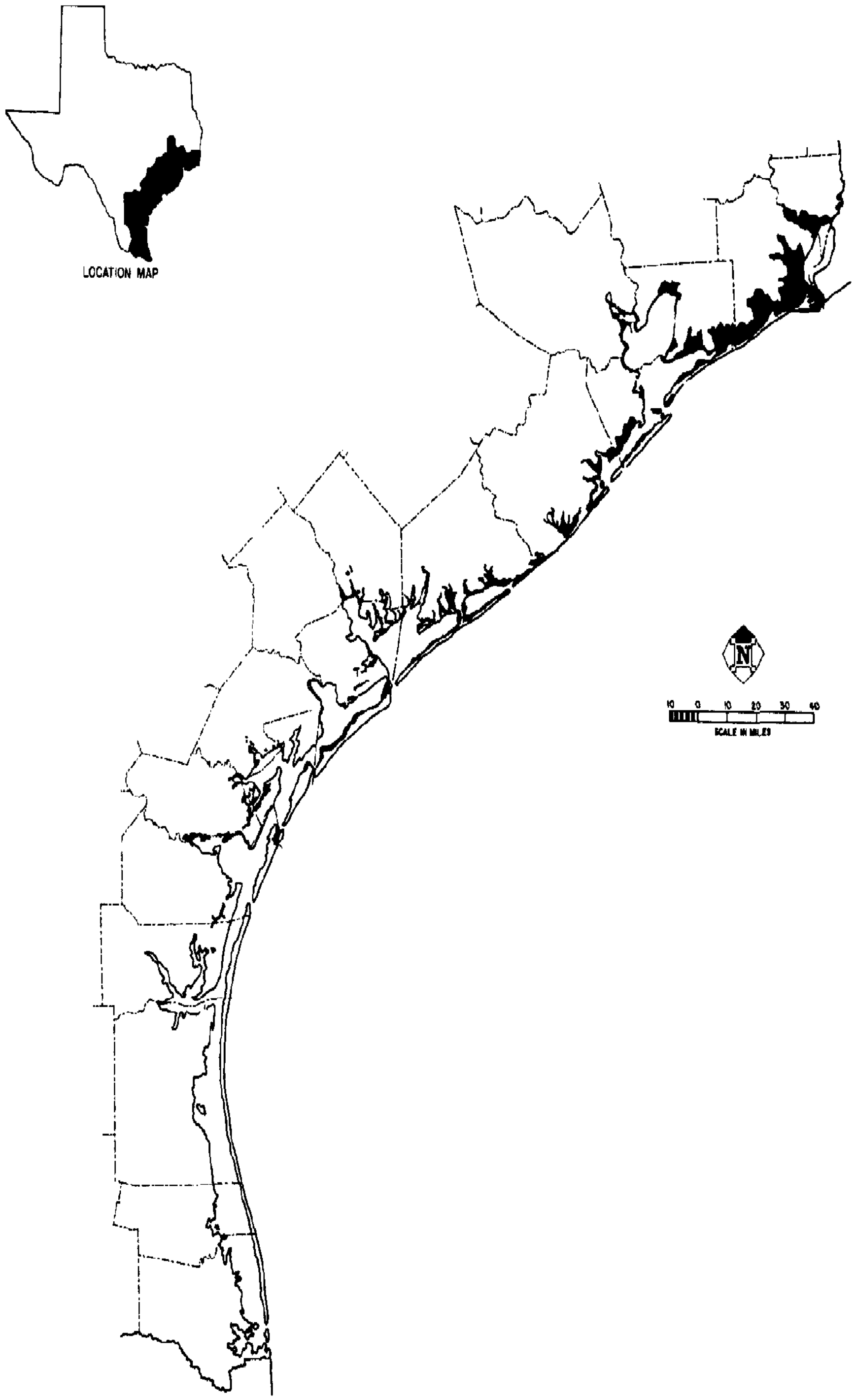

PLATE I-D.

MARSHLANDS IN THE COASTAL ZONE

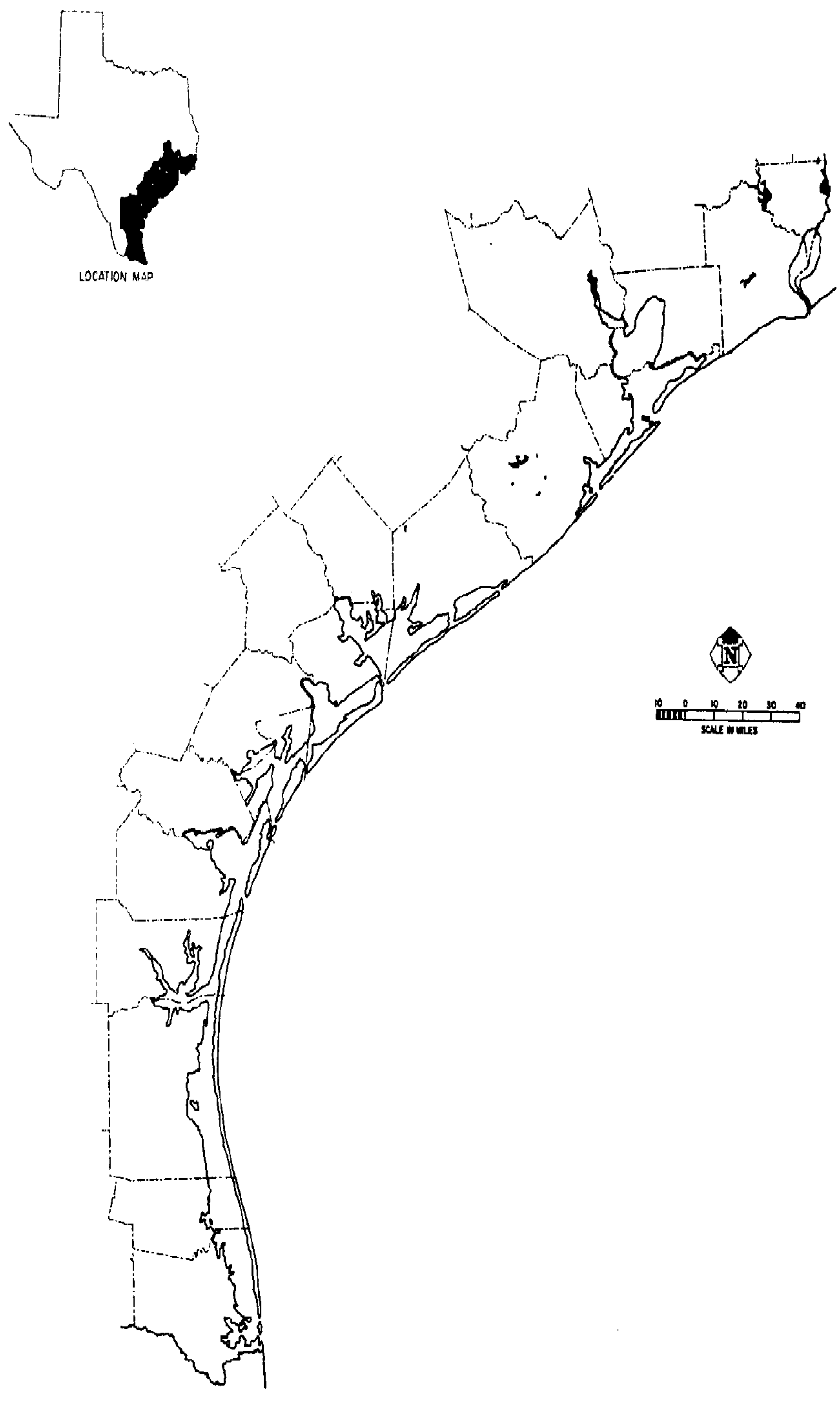

PLATE I-E.

SWAMPLANDS IN THE COASTAL ZONE

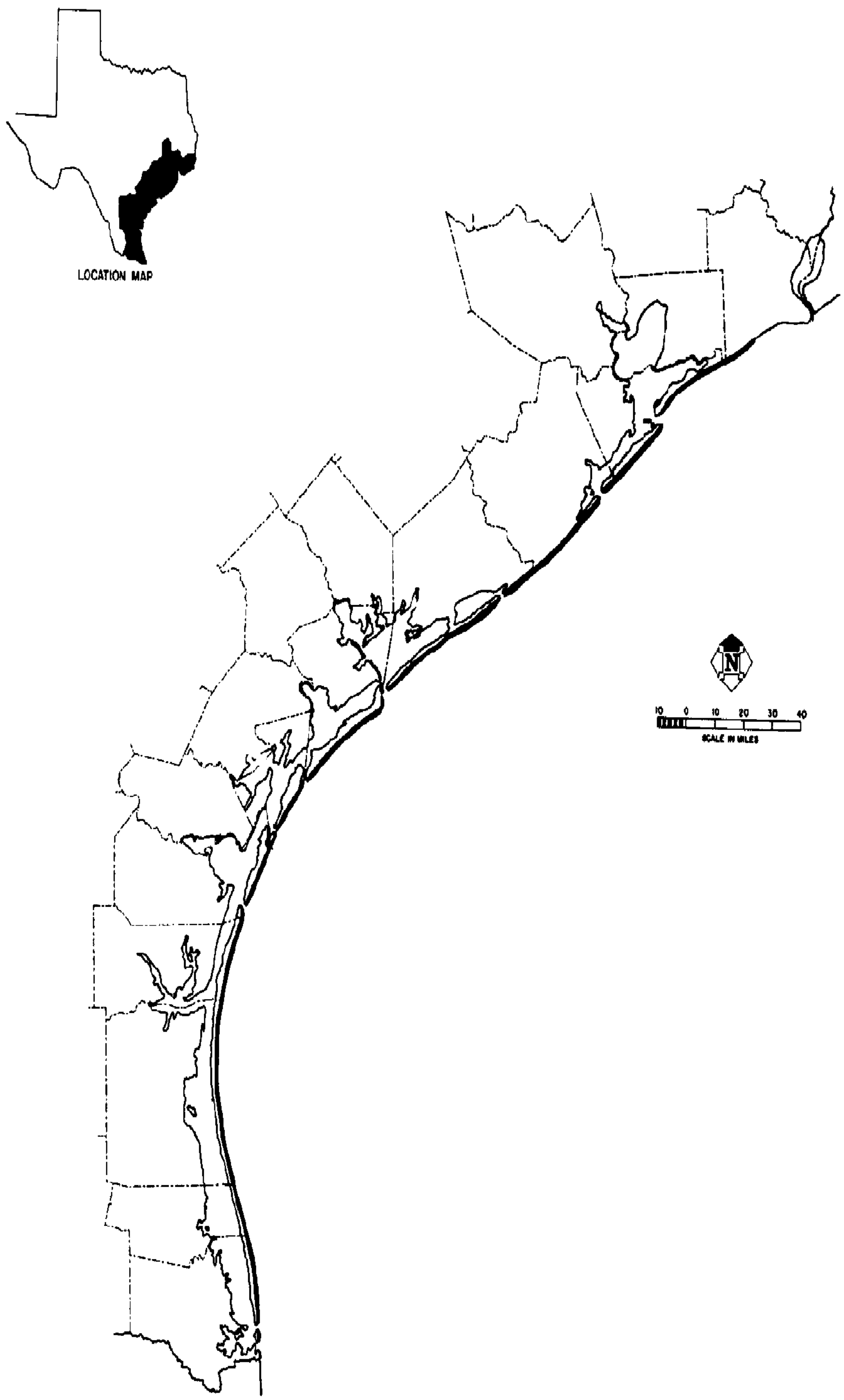

PLATE I-F.

RECREATIONAL BEACHES IN THE COASTAL ZONE

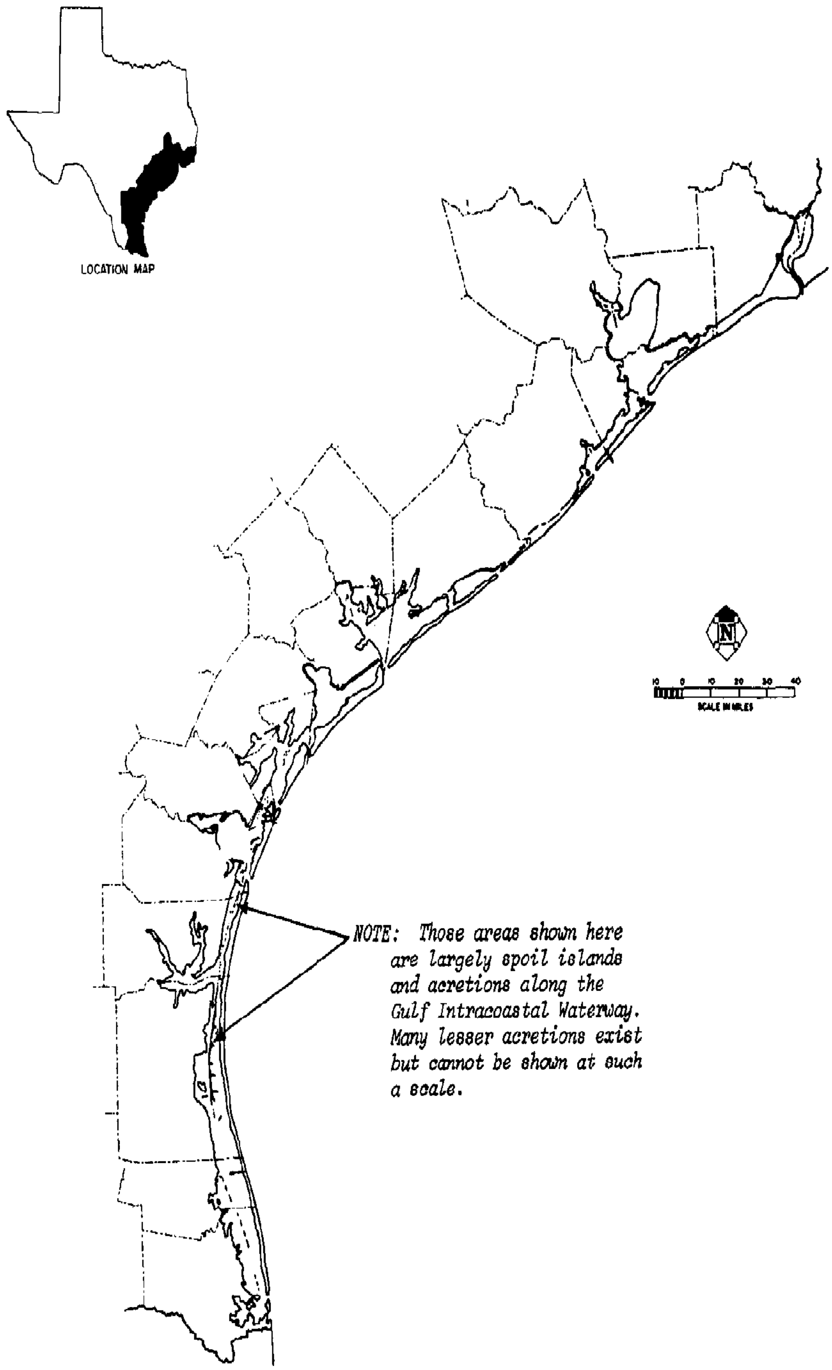

PLATE I-G.

SPOIL ISLANDS AND OTHER BUILT-UP LANDS

IN THE COASTAL ZONE

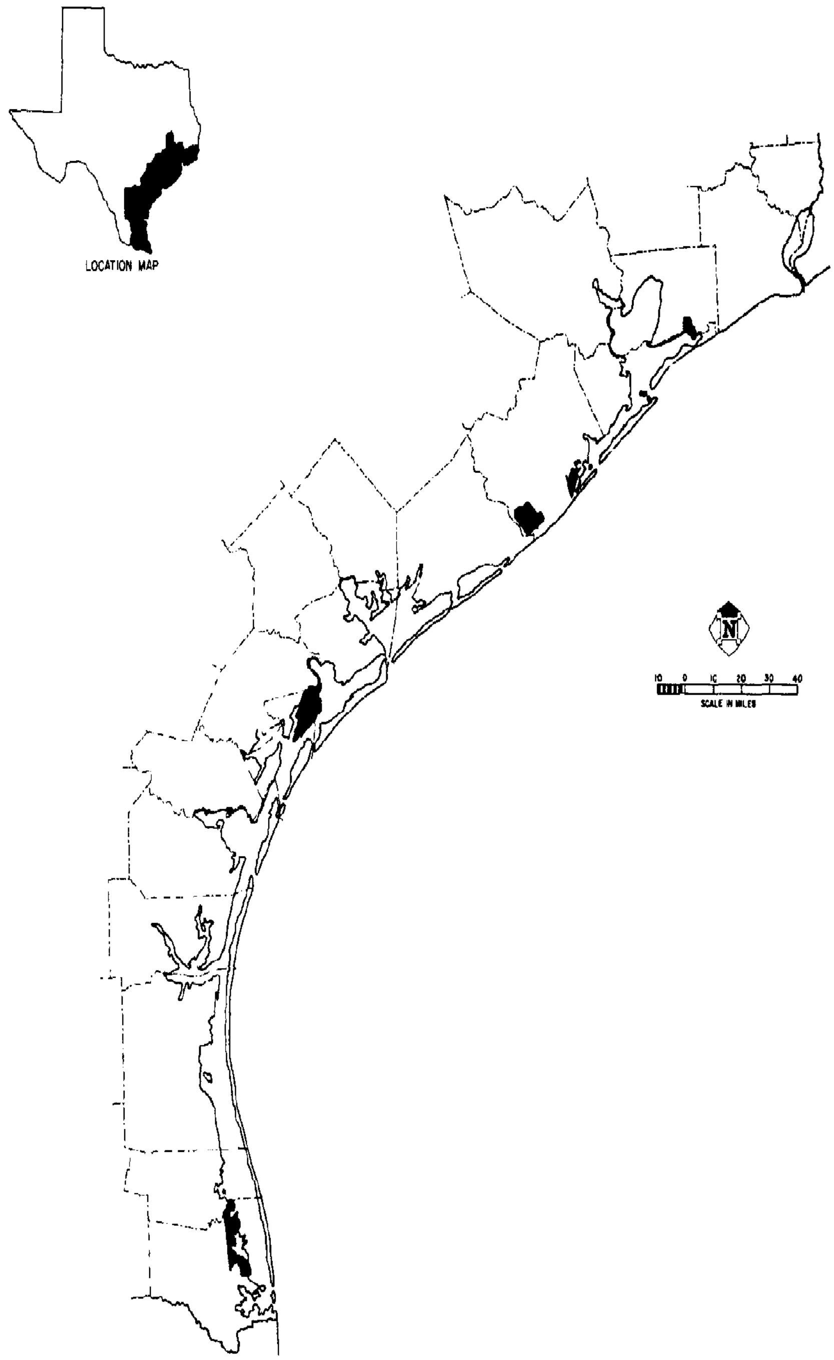

PLATE I-H.

FORMAL WILDLIFE REFUGES IN THE

COASTAL ZONE

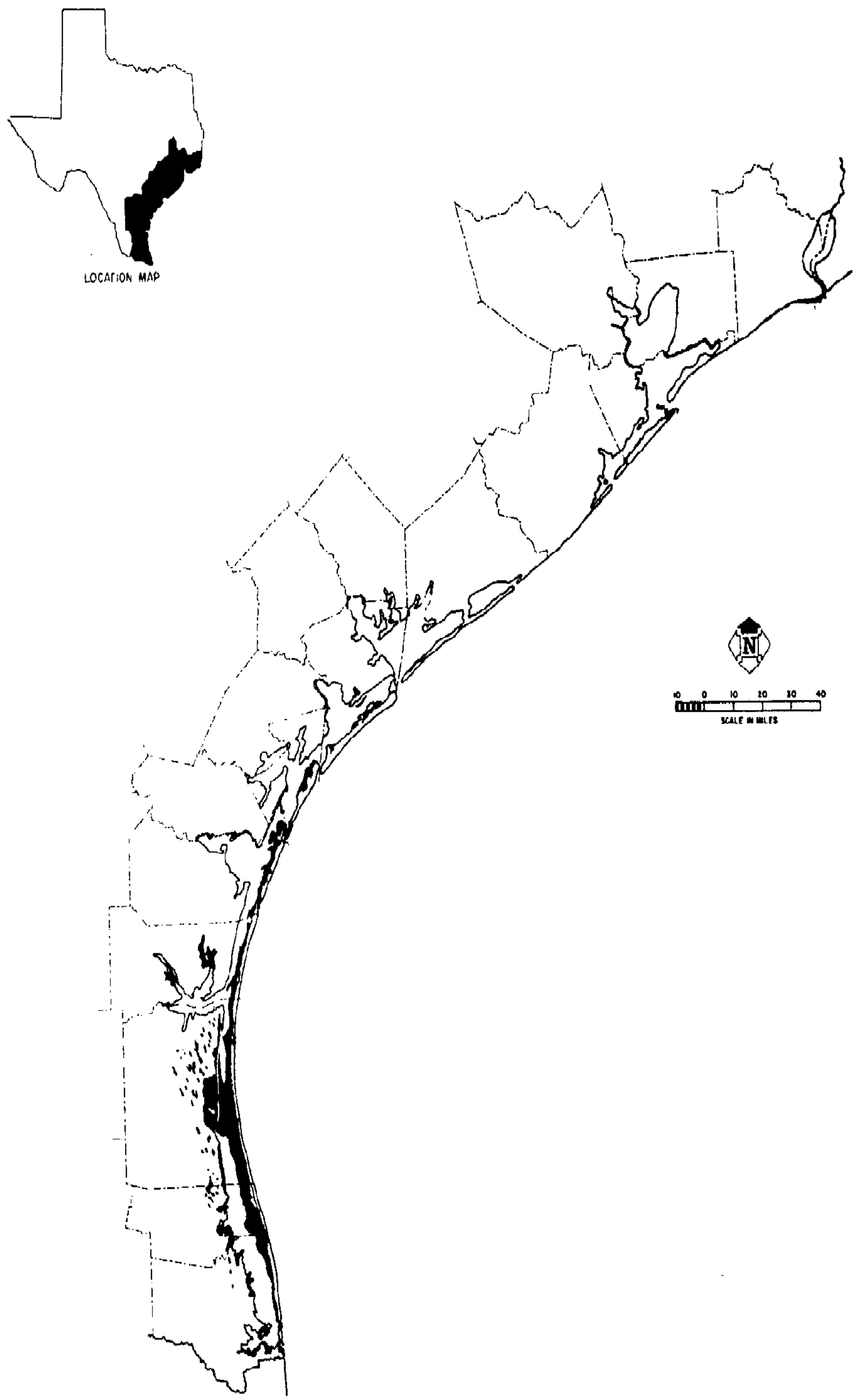

PLATE I-I.

BARREN LANDS IN THE COASTAL ZONE

ATTACHMENT A

Purpose

The Environmental Geologic Atlas is designed to provide critical information for planning and land use in the populous and industrial coastal zone of Texas and for a better understanding of physical, biological, and chemical environments of the coastal zone in order to assess and judge properly the status of these resources.

Approach

Detailed mapping and study in the field and by light aircraft; geologic environments, sediments, landforms were mapped on 1:24,000-scale aerial photographs. Approximately 20,000 square miles of coastal zone from shoreface to about 50 miles inland (see index).

Status

Four geologists and several technicians and cartographers have worked for 18 months on the project. All mapping is now complete and the maps and report are in preparation for publication.

Contents

The Environmental Geologic Atlas of the Texas Coastal Zone will consist of a folio of 63 geologic and multi-colored environmental maps accompanied by text explaining use and interpretation. The coastal zone was divided into seven map areas: Brownsville-Harlingen, Kingsville, Corpus Christi, Port Lavaca, Bay City-Freeport, Galveston-Houston, and Beaumont-Port Arthur. For each of the areas, the following maps were prepared:

> *Environmental Geologic Maps:* scale 1:125,000; total of 125 map units including landforms, sediments, bedrock, and certain plant communities; Bureau-constructed base map includes 5-foot contours, 3-foot bathymetric lines, paved roads, cities, pipelines, and other physical and cultural information. Emphasis has been on mapping basic units from which a variety of data can be derived.
>
> *Land-Use Maps:* Inventory (25 map units) of present use including agriculture, range, woodland-timber, wildlife, spoil and made land, recreation, residential-urban, industrial, and sewage disposal.

Water Systems - Man-made Features: Inventory (15 map units) of made land, types of spoil land, jetties, piers, sea walls, rivers, lakes, sloughs, estuaries, reservoirs, canals and ditches, channels, and tidal inlets.

Engineering Properties: Distribution (15 map units) of properties such as water-holding capacity, compressibility, shrink-swell, drainage, relief, shear strength, plasticity, flooding, permeability, mineral content, faults, and other features.

Biologic-Assemblage Map: Approximately 45 subaerial plant and subaqueous animal communities.

Physical Processes Map: Hurricane surge and flood areas, shoreline erosion, equilibrium and deposition, circulation patterns, sediment dispersal, tidal data.

Salinity-Climatic Maps: Contoured salinity in bays and estuaries during droughts and rainy seasons, average salinity; graphs of salinity for each bay and estaury; rainfall data; water and sediment discharge for rivers entering coastal zone.

Mineral and Energy Resources Map: Approximately 15 units including source of sand and clay, oyster reefs, utility lines, pipelines, quarries, oil-gas fields, sulfur fields, salt domes, cement plants, power plants, brine wells and other data.

Depositional Systems Map: Display of active or ancient genetic units such as fluvial, deltaic, marsh, swamp, barrier-cheniers, bay-lagoon-estuary, eolian and off-shore systems.

Publication Date

The folio will be available during the first half of 1971.

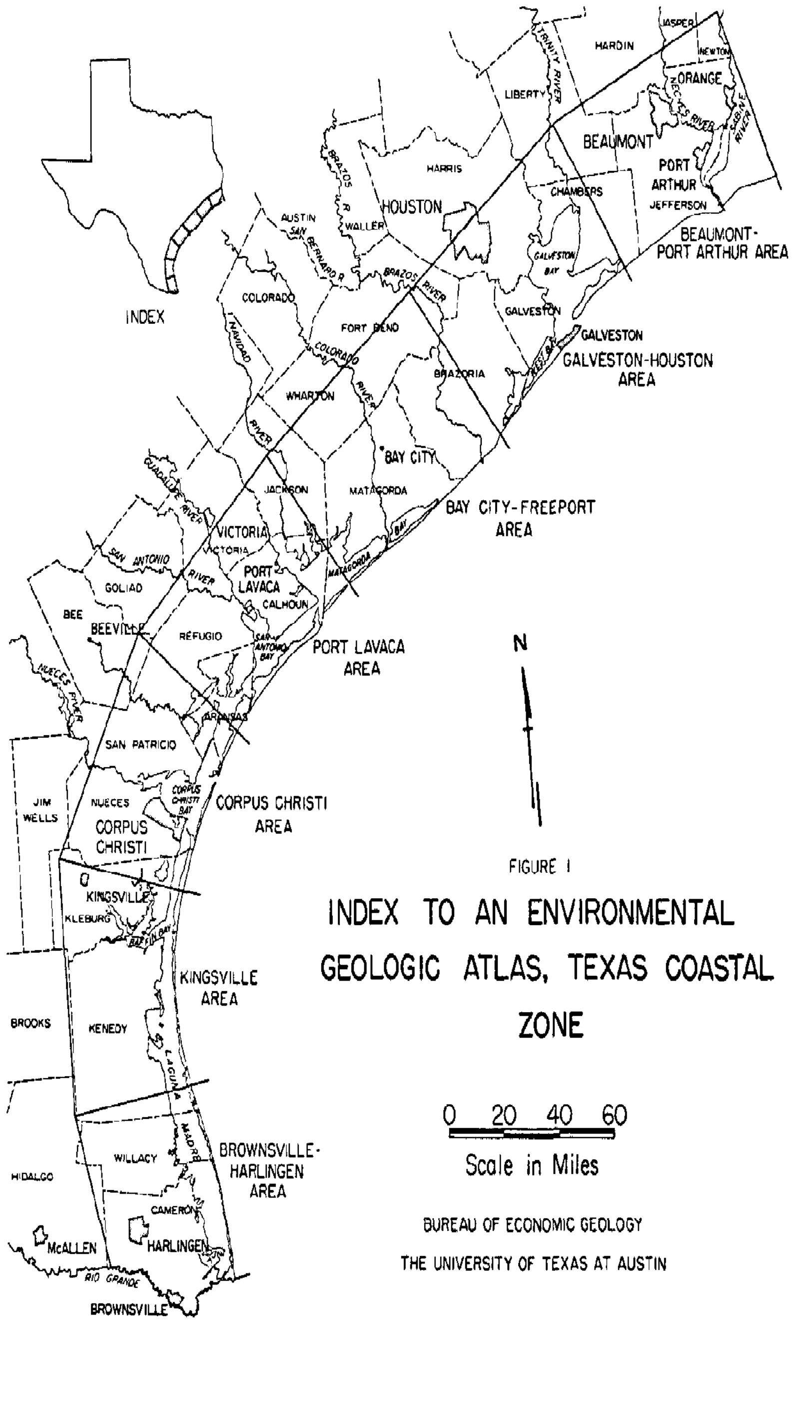

FIGURE I

INDEX TO AN ENVIRONMENTAL GEOLOGIC ATLAS, TEXAS COASTAL ZONE

BUREAU OF ECONOMIC GEOLOGY

THE UNIVERSITY OF TEXAS AT AUSTIN

THE WILDLIFE RESOURCES
OF COASTAL TEXAS

Prepared by

Dr. Hans A. Suter

January 1971

for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

ACKNOWLEDGEMENT

It is a pleasure to acknowledge the help of the following individuals in compiling this survey report.

Dr. Henry Hildebrand, University of Corpus Christi

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Dr. Clarence Cottam, Welder Wildlife Foundation

Mr. Ernest Simmons, Texas Parks & Wildlife, Rockport

Mr. Gordon Hansen, Aransas National Wildlife Refuge

Mr. Russell Clapper, Anahuac National Wildlife Refuge

Dr. Alan Chaney, Texas A & I University, Kingsville

Without their cooperation in sharing their data, observations, and comments this report could not have been written. However, I am totally responsible for the conclusions..

THE WILDLIFE RESOURCES OF COASTAL TEXAS

INTRODUCTION

Texas has the third longest coastline of the 48 states which make up the contiguous part of the United States. Only California in the west and Florida in the east can lay claims to a more extensive boundary between land and sea. In spite of this long coastline Texas is generally not considered a maritime state. More importantly, most Texans do not think of themselves as citizens of a maritime province.

Governor Preston Smith is to be commended for being the first governor in the history of Texas to recognize the maritime nature of the state. Under his leadership the first conference of Texas coastal resources and goals was held in Houston on September 10 and 11, 1970. The *61st Texas Legislature* is to be congratulated for appropriating funds to initiate a study of coastal resources and to commence statewide comprehensive planning for the orderly development of the coastal resources of Texas.

The Texas coast bathed by the waters of the Gulf of Mexico extends for 367 miles from the mouth of the Rio Grande in the extreme southern tip of the state to Sabine Pass on the eastern border of Texas with the State of Louisiana. In reality Texas' coastline is considerably longer than the 367 miles stated, because our coast is made up of a complex system of bays, lagoons, and estuaries protected from the open Gulf of Mexico by slender barrier islands or peninsulas. *Taking these indentions into account Texas' coastline measures 624 miles.* Texas inland waters which are affected by the tides cover some 1.3 million acres.*

DEFINITION OF WILDLIFE

Webster's Third New International Dictionary defines wildlife as: *"Living things that are neither human nor domesticated; especially: the mammals, birds, and fishes that are hunted by man for sport or food."* For purposes of this survey we will select a definition of

**This figure can vary depending on how far into these indentions one goes.*

wildlife considerably narrower than "living things that are neither human nor domesticated" but also broader than "the mammals, birds, and fishes that are hunted by man for sport or food."

For obvious reasons we cannot discuss all living things (except human or domesticated) that occur in the Texas coastal zone. The mere listing of species of plants and animals found on our coastal zone would far exceed the space and time limitations of this survey. On the other hand, to restrict the meaning of "wildlife" to huntable species would be too narrow.

Modern man is becoming increasingly concerned with species of animals that have no direct importance as game. For example we might call attention to the increasing number of people who are amateur birdwatchers and are just as interested in non-game birds as game birds. Shell collectors are another category of people who deal with non-game animals which populate the coastal zone. Therfore we would like to define "wildlife" as: .*Those species of undomesticated animals which are important to man from the point of esthetics as well as economics. Insects as well as most invertebrates will not be considered as "wildlife."*

DEFINITION OF COASTAL ZONE

The Texas coastal zone, the area to which the present survey applies, can be defined in a variety of ways. We have chosen, however, to adopt essentially the definition of the "coastal zone" given by Dr. Peter Flawn of the University of Texas at Austin at the Governor's Conference in Houston in September. Dr. Flawn defines the coastal zone as that area occupied by the twelve counties which abutt directly on the Gulf of Mexico. Starting at the border with Louisiana the following counties are included: Jefferson, Chambers, Galveston, Brazoria, Matagorda, Calhoun, Aransas, Nueces, Kleberg, Kenedy, Willacy, and Cameron. The area within these counties amounts to 9,938 square miles or 3.61% of the total area of the state of Texas. Six additional counties, Orange, Harris, Jackson, Victoria, Refugio, and San Patricio, have direct access to coastal bays and should be included within the coastal zone. These additional counties occupy an area of 4,265 square miles or 1.55% of the area of the state. Consequently, the coastal zone is made up of eighteen counties with a total area of 14,203 square miles, or 5.16% of the landlocked area over which Texas has jurisdiction.

CLIMATE

The Texas Gulf Coast is located in a variable climatic belt. Although average July temperatures are uniformly between 80 to 90 degrees Fahrenheit, January temperatures average 50 degrees Fahrenheit in the eastern extremes of the coast and 60 degrees Fahrenheit in the soughern extremes. In between these values the average January temperature is recorded as 55 degrees Fahrenheit.

Creater variability in climatic conditions in the coastal zone is manifested by the average yearly rainfall. The following tabulation (data taken from Texas Almanac: 1970/71 edition) gives an idea of the yearly average rainfall in the eighteen coastal counties.

COUNTY	RAINFALL (inches)
Orange	55.8
Jefferson	53.1
Chambers	51.6
Harris	46.0
Galveston	41.8
Brazoria	49.2
Matagorda	40.6
Jackson	37.9
Calhoun	36.8
Victoria	36.2
Refugio	33.8
Aransas	33.2
San Patricio	30.6
Nueces	28.3
Kleberg	26.5
Kenedy	26.6
Willacy	26.5
Cameron	26.1

No other stretch of the U. S. Gulf coast shows as much variability in rainfall as that portion which belongs to Texas.

PHYSICAL FEATURES AND SOILS

The Coastal Zone of Texas can be divided into two major portions: *the Coastal Prairie* and the *Gulf Coast Marshlands*. The Gulf Coast Prairie is a nearly level, slowly drained plain less than 150 feet in elevation, with numerous sluggish rivers, creeks, bayous, and sloughs. It is characterized by level grasslands that support ranching and farming, low woodlands especially along streams, swamps and fresh-water marshes. The Coast Marsh area is limited to narrow belts of low wet marsh interspersed with dunes immediately adjacent to the coast.

Soils in the Coastal Marsh area are acid sands, sandy loams and clays. The upland prairie soils tend to be heavier textured clays or clay loams, although there are some sandy loams. In general, soils have slowly permeable profiles. The soil moisture is not readily available to the vegetation. Typical range sites include blackland, sandy prairie, lowland flats. coastal sands, salt meadow, and salt marsh.

Most of the marsh is grazed by cattle in large land holdings. Ranches and rangelands of the uplands of the Gulf Prairies are interspersed with farms. The better soils are highly productive under cultivation or as improved pasture or native range. Wildlife, particularly deer, are an important consideration in management of vegetation.

VEGETATION

The climax vegetation of the Gulf Priaries is largely grassland (tall grass prairie) or post oak savannah. However, much of the area has been invaded by trees and brush such as mesquite (Prosopis glandulosa), oaks, especially live oaks (Quercus virginiana), prickly pear (Opuntia spp.) and several acacias. The principal climax plants are tall bunch grasses such as big bluestem (Andropogon Gerardi), seacoast bluestem (Schizachyrium scoarium var. littoralis), Indian grass (Sorghastrum avenaceum), eastern gamagrass (Tripsacum dactyloides), species of Panicum and others. Some invading plants, other than brush species, include yankee weed (Eupatorium compositifolium), broomsedge (Andropogon virginicus), smutgrass (Schedonnardus paniculatus) and many annual weeds and grasses.

The salt marsh areas typically support several species of sedges and rushes such as Carex, Cyperus, Eleocharis, Juncus, and Scirpus, several cord grasses (Spartina spp.) and seashore saltgrass (Distichlis spicata).

Introduced grasses such as Bermuda (Cynodon dactylon) and carpet grass (Axonopus affinis), are common in tame pastures and some have escaped into uncultivated areas.

The river bottoms which cross the Gulf Prairies contain a flora quite distinct from the prairies themselves. Here, trees predominate such as oaks (Quercus spp.), hackeberry (Celtis spp.), willows (Salix spp.), ash trees (Fraxinus spp.), cottonwoods (Populus spp.), anacua (Ehretia anacua) and others. Dwarf Palmeto (Sabel minor) is also found in these river bottom lands.

Conifers are not an important family in the coastal zone. However, especially in the eastern counties, some representative species occur such as the shortleaf pine (Pinus echinata), the longleaf pine (Pinus palustris) as well as the loblolly pine (Pinus teada). The bald cypress (Taxodium distichum) is found in swamps and along rivers from Brazoria County eastward.

On barrier islands, especially on Padre and Mustang Islands, the predominant vegetation is sea oats (Uniola paniculata), marshhay cord grass (Spartina patens) and the creeping vines of morning glory (Ipomoea spp.). Sunflowers (Helianthus spp.) are common on these treeless expanses of sand dunes.

Aquatic plants abound in the coastal zone. Among these are parrot's feather (Myriophyllum spp.), pondweeds (Patomogeton spp.),

THE GOOD FISHING AT ROLLOVER PASS TAKES ITS TOLL IN ENVIRONMENTAL DEGRADATION.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

duckweeds (Lemna spp.), duck meat (Nuphar luteum) and arrowheads (Sagittaria spp.). *The beneficial aquatic plant species as well as open water for fish and wilife in many of the streams, canals, lakes, and ponds are being threatened by several introduced noxious weedy species.* Foremost among these are the water hyacinth (Eichhornia crassipes) and alligator weed (Althernanthers philoxeroides). The native cat-tails (Typha spp.) also belong here. Other species that can and may prove to be troublesome are aquatic species of water-primrose (Ludwigia spp.), water lettuce (Pistia stratiotes), common frogbit (Limnobium spongia) and American featherfoil (Hottonia inflata). In bays and open water along the Gulf Coast are to be found such species as manatta-grass (Cymodocea filiformis), widgeon-grass (Ruppia maritima), shoal-grass (Halodule Beaudettii), turtle-grass (Thalassia testudium) and others. Some of these marine grasses are often found washed up on the beaches along the coast.

ANIMALS

a. General

To most people "wildlife" means those animals which are hunted for food or sport. In today's society, wildlife, with the exception of fish and shellfish, supply only an insignificant part of the diet of the average Texan. This becomes especially apparent when we consider that our laws do not allow the sale of meat derived from wild species; again fish and shellfish are excepted. This statement does *not* imply that wildlife is of little importance in the economy of Texas.

Hunting and sport fishing are major hobbies in Texas. The revenue derived from the sale of hunting and fishing licenses is only a minor item in the State's revenue. In the fiscal year which ended August 31, 1968, Texas issued nearly 855,000 resident hunting licenses and over 1.2 million fishing licenses. These amounted to a total income of some *5.2 million dollars*. The total income for Texas from hunting and sport fishing is many times this amount derived form taxes on sales of equipment, transportation, food, lodging, etc. The U. S. Census in 1960 estimated that *Texans spent in that year $383 million for hunting and fishing*. This amount has increased considerably but more up-to-date statistics are unavailable.

The number of people whose hobbies are directly related to nature, such as birdwatchers, shell collectors, hikers, wildlife photographers and others is unknown. Their numbers are far more difficult to assess, for no license is required to pursue these activities. But again the amount of cash expended by these falls into the multimillion dollar bracket. An interesting item in this respect is given in the May 1970 issue of Executive's Digest: "In 1940 the American consumer spent about $3.7 billion for recreation and leisure living. By 1960, this figure had climbed to $18.3

DEER HUNTING IN THE COASTAL ZONE IS GOOD.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

billion. In 1968, a mere eight years later, the figure had increased to $32.5 billion. The estimate for 1977 is $62.5 billion." Obviously, not all of these expenditures for leisure and recreation are related to nature and wildlife but somewhere between one third and one half of these monies are spent on outdoor activities. Therefore, from straight economics, wildlife is a major resource.

b. Huntable Species

A quick glance at the hunting situation in the fall of 1970 can be obtained from News, published weekly by the Texas Parks and Wildlife Department. The issue published the first week in December gives this picture of hunting in coastal Texas:

Deer hunting in the southeastern portion of the state got off to a slow start because of high wind. Clarence Beezley, information and education officer in La Porte, says there seems to be plenty of deer, but hunters are having to wait for better hunting conditions. Range conditions are good with plenty of water standing in the marshes, but it gets drier the farther west one goes.

Duck hunters are still getting their limits, and Beezley says most hunters are happy with the new point system for determining bag limits. Beezley says pintail drakes are about the only ones unhappy with the new system since they, being 10-point ducks, are getting plenty of pressure.

Squirrel and rabbit hunters have been doing well, but most of the interest is in deer and waterfowl.

Counties which normally have quail are experiencing a drought which could mean trouble for quail later on in the year. Dove were scattered during the season, and the kill was about average.

South Texas, where the big deer usually are, has them again this year with better than average size in the northern part of the region, according to L. D. Nuckles, information and education officer in Rockport. But generally the range in all but the most southern portion of the region is in poor shape, and the deer, although in good shape now, are starting to lose weight. Because of the warm weather, the deer are not moving and hunters have had only moderate success.

Turkey populations are generally the same as last year but somewhat higher in the north of the region.

Quail populations are high, but hunters need a good dog to find them in the thick brush, according to Nuckles.

The duck season has been only fair because of the clear weather. Nuckles says a good, wet cold front is needed to bring the ducks down into gun range.

DUCKS, ALTHOUGH DECREASING IN NUMBER, ARE STILL PLENTIFUL THROUGHOUT THE COASTAL ZONE.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

DUCKS IN FLIGHT

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

An interesting development in the yearly migration patterns of waterfowl is emerging this year. Blue and snow geese, as well as mallards, species which breed in Canada and northern U. S. during the warm season and seek refuge during the winter on the Gulf Coast are induced to stop on refuges in the Midwest. The feeding of these game birds on federal and state refuges along the flyways is affecting the number of birds along our coast. Biologists fear that the high concentration of birds on these small refuges in the Midwest could have disastrous consequences due to heavy hunting pressure, an outbreak of disease (fowl cholera) or rigors of the winter.

Clearly, interstate cooperation is necessary in the wise management of this valuable wildlife resource.

In spite of these attempts to hold water fowl in midwestern refuges a great number of ducks fly each autumn to the Texas Gulf Coast. They remain here until early spring when they return to their northern breeding grounds. *In sheer numbers two duck species predominate in Texas bays and lagoons: pintails and redheads.* Although redheads occur in large numbers especially in the Laguna Madre the species is not in as good shape as the pintail. It has been estimated by Weller (Journal of Wildlife in Management, 28, (1), 64-103, 1964) that *78% of all redheads winter in the Laguna Madre.* Manifestly, Texas has a responsibility of maintaining a suitable habitat for this species.

The U. S. Government maintains on the Texas Coast four refuge areas which are wintering ground for migratory water fowl. In the lower Laguna Madre in Cameron County is located Laguna Atascosa National Wildlife Reguge. Mainly in Aransas County we find Aransas National Wildlife Refuge, famous as the winter home of the rare whooping crane. On the upper coast two smaller refuges have been established, Brazoria and Anahuac National Wildlife Refuges in Brazoria and Chambers Counties, respectively.

In contrast to the federal refuges, the State of Texas has only one area the purpose of which is management of water fowl: the J. D. Murphree Wildlife Management Area just outside Port Arthur in Jefferson County. While federal refuges prohibit hunting of water fowl within their boundaries, the state wildlife management area permits restricted hunting of ducks during the regular season.

c. Sport Fishing and Commercial Fishing

Generally speaking, sport fishing on the Texas Gulf Coast is *more important* than hunting as a hobby. The reason for that is twofold. While hunting is restricted by law to a relatively short season (from September for white wing and morning doves through the deer, turkey and water fowl season in November and December to the quail season which closes on January 31) there

CRABS ARE ABUNDANT IN TEXAS' FERTILE ESTUARIES.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

SPORT FISHING ON THE TEXAS GULF COAST IS EVEN MORE POPULAR THAN HUNTING.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

THIS MONSTER RAYFISH WAS HARPOONED OFF PORT ARANSAS.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

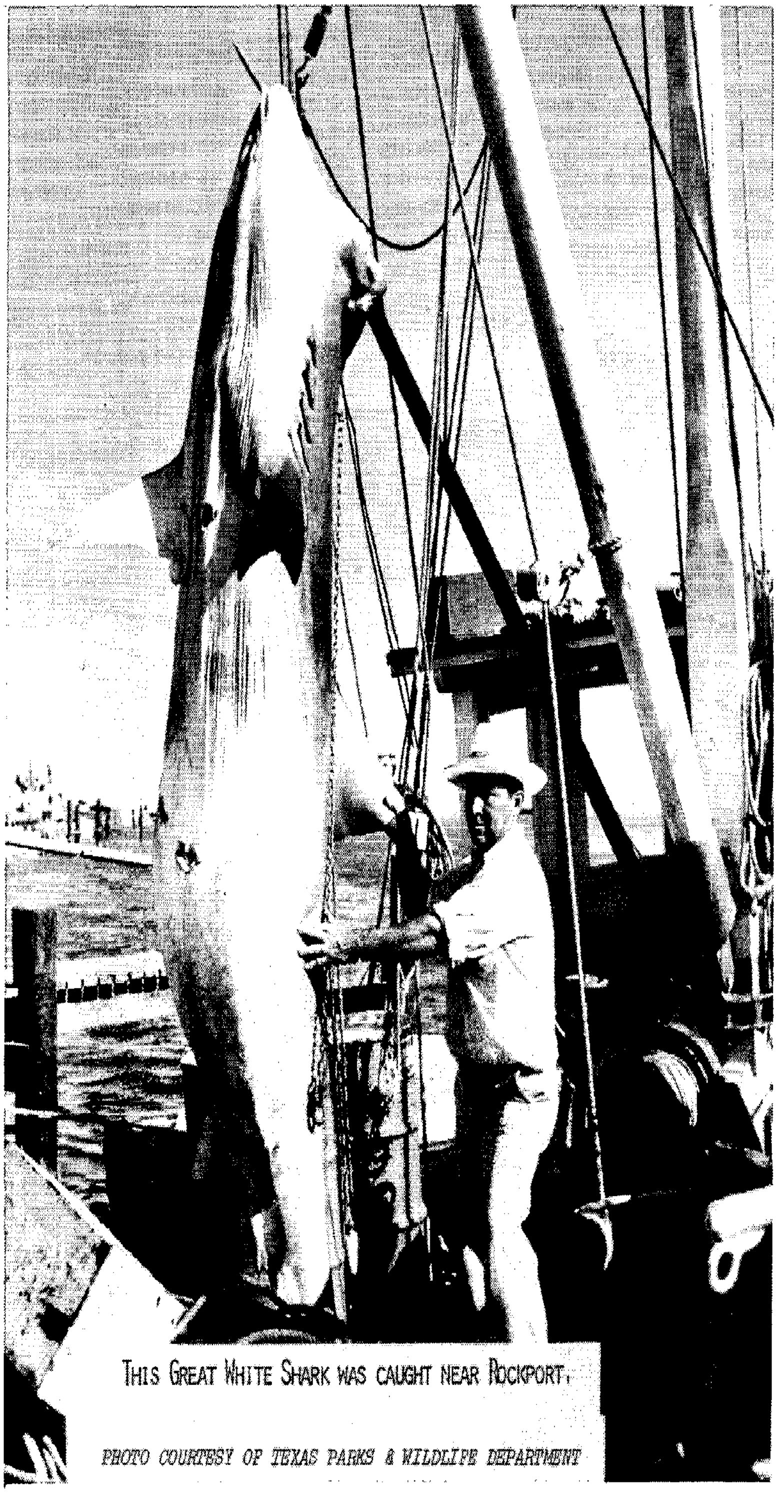
is no season on fishing. The mild climate of the Texas Gulf Coast permits the pursuit of fishing the year round. An additional reason for the preference of fishing over hunting is the fact that Texas has very little public land and access to private land is obtained only through some kind of lease arrangement between the owner of the land and the hunter. In contrast, fishing waters are in the public domain and accessible to any fishing license holder.

On the Texas Gulf Coast two types of fishing are available: fresh water and salt water fishing. *Generally speaking, salt water fishing is far more important than fresh water fishing. Here again the decisive factor is accessibility.* Especially on the lower coast, from San Antonio Bay south, fresh water is not readily available. Rivers flow through private land and although a stream is in the public domain it can be reached without incurring tresspassing charges only where it flows through public land such as a highway easement. Even freshwater reservoirs, which were constructed with public funds, have restricted access. For instance, Lake Corpus Christi, a reservoir with a shoreline in excess of 200 miles, has less than 10 miles of shore where the public has free access. This injustice, with the public paying for a reservoir but only vested interests having access to its shores, has been corrected. Reservoirs built with federal funds - Corps of Engineers or Bureau of Reclamation - must provide a 300 foot easement above the high water mark around the entire reservoir to which the public has free access.

Salt water fishing falls into two distinct categories. The *bay fishing* which can be enjoyed with a modest expenditure of equipment and the *open Gulf fishing* which requires considerable investment in a seaworthy craft or payment of sizable charter fees on boats for hire. The importance of Texas in the sports world of deep sea fishing is recognized by the fact that four fishing tournaments are held on our coast. The oldest one is off Port Aransas which began in 1932 and has continued annually with a short interruption during World War II. Next follow the tournaments at Port Isabel, Freeport, and Port Lavaca. These yearly events attract a large number of fishermen from throughout the state.

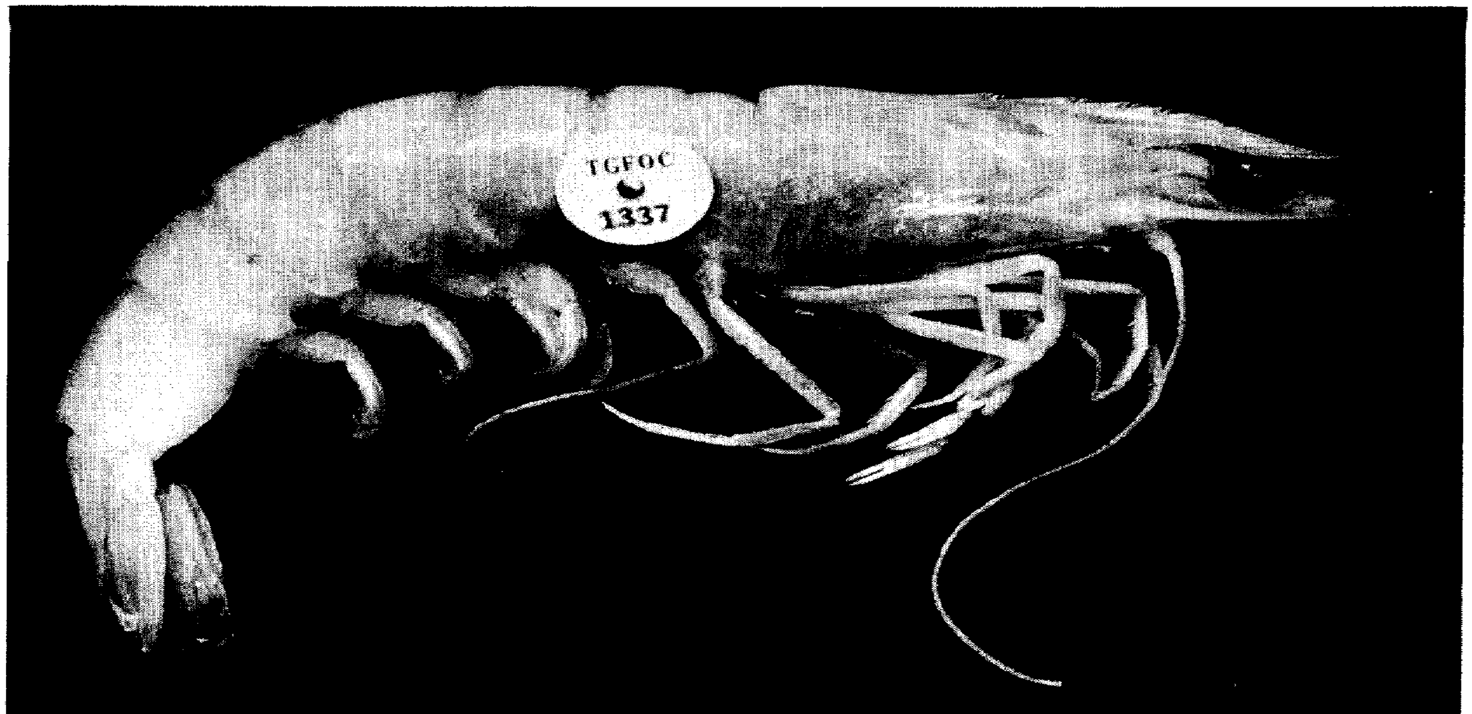
Fishing, fresh water as well as salt water, is the outdoor sport enjoyed by the largest number of people. It does not only provide an excellent activity but for the poor a modest investment in equipment provides recreation and a chance to supply essential protein for their diet. Therefore, the maintenance of a good environment for fish as well as shell fish should have a high priority when the welfare of the disadvantaged in our society is considered.

The importance of commercial fisheries in Texas can be evaluated from landings of marine species in Texas ports. These statistics are compiled by the U. S. Department of the Interior, U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries



THIS GREAT WHITE SHARK WAS CAUGHT NEAR ROCKPORT.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT



50% OF THE WORLD'S SHRIMP DEPEND ON THE TEXAS ESTUARINE COMPLEX.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

in cooperation with the Texas Parks and Wildlife Department. In 1969 the total landings for finfish in Texas ports amounted to *78.5 million pounds*. Of this total, *73.2 million pounds were Menhaden*, a fish unsuitable for human consumption, but sought after for its oil and as a source of animal food. Drum catch, both black and red (redfish), amounted to 1.7 million pounds and the spotted sea trout harvest totaled 1.2 million pounds. Therefore, *four species of fish accounted for 97 per cent of the total commercial finfish landings in Texas*.

More important than finfish landings in 1969, both from total poundage as well as value, were the landings of shellfish. The total shellfish landings amounted to *80.9 million pounds* and were distributed in the following fashion: shrimp (all species) 70.8 million pounds, blue crabs 6.3 million pounds and oyster meats 3.8 million pounds. *Obviously, shrimp is by far the most important commercial harvest from the sea.* The total value of the fisheries catch landed in Texas ports depends very greatly whether one multiplies the catch by the price paid to the fisherman or the price the consumer has to pay at the neighborhood supermarket for some product of marine origin. Equally important are seasonal fluctuations in market prices.

It is imperative, however, to realize that the income for the State and its citizens derived form sport or commercial fisheries is income derived from a *truly renewable natural resource*. If proper management is provided, from a point of view of harvest as well as maintenance of suitable habitat, this source of income is inexhaustible. *It is like living off the interest of an investment without drawing on the capital.*

But although many of the Texas landings of finfish and shellfish are caught in the waters of the open Gulf, it is important to keep in mind that *some 90 percent* of the species spend significant parts of their life cycles in the waters of Texas estuaries and bays. *Shrimp*, for instance, spawn in the Gulf but seek the nutrient-rich estuaries to change into adult forms. *Oysters*, a sedentary species, need some salt content in the waters they inhabit but cannot grow in the salinity of the open Gulf. Therefore, the maintenance of healthy estuaries, *free of pollutants* and *supplied with adequate amounts of fresh water*, is essential to the perpetuation of the fishery resources of Texas.

d. Non-game Birds

In the words of Roger Tory Peterson, possibly the foremost modern field orinthologist, *Texas is the No. 1 Bird State*. More than 540 species of birds have been recorded in Texas, not counting subspecies. If subspecies are included the number exceeds 800. No other state in the U. S. can boast a larger diversity of birds within its boundaries.

The reason for this diversity of bird life lies in the geographic location of Texas. The Rocky Mountains form a natural barrier along the U. S. but in Texas western species as well as eastern species are to be found. Also, we are located at such a latitude where the birds of the northern plains meet species of birds of Mexico.

Although the Texas Gulf Coast does not have records for sighting of all birds species which occur in the state, it is estimated that some *400 species* have been seen in the coastal zone. One reason for the variety of birds along the Texas coast is the fact that the coast lies across two major migratory routes of birds. The eastern part of the coast lies within the western limits of the Mississippi flyway and the rest of the Texas coastal zone is crossed by the Central flyway. Consequently, the greatest variety of birds is found during migration, in the spring and again in the fall. Texas, especially the Gulf Coast, is a true Mecca for birders and visitors from all states of the Union as well as from foreign countries seek out our Gulf Coast to observe and study birds.

In addition to the geographic location, Texas' Coastal Zone offers a variety of habitat to many birds. The long expanses of mud flats and beaches along our shores attract the shore birds, the low water areas in our bays offer food for many wading birds, and the prairie interspersed with brush and tree motts offer suitable cover for a great number and variety of birds. This habitat exists because the human population along the coast is concentrated in four metropolitan areas separated from each other by sparsely inhabitated expanses of land. The metropolitan areas with high population densities are: Brownsville-Harlingen, Corpus Christi, Houston and Beaumont-Port Arthur-Orange. Aside form these metropolitan areas industry is rather rare along our coast.

Texas cannot only boast the greatest variety of birds of any of our 50 states, but the Lone Star State can also lay claim to the destinction of being the *home of more rare and endangered birds species than any other state in the U. S.* Again, the Coastal Zone is permanent or temporary home to many of these endangered species.

e. Rare and Endangered Species

The U. S. Fish and Wildlife Service yearly publishes a list of animal species, not only of birds, which are considered in danger of extinction. The 1968 edition of the Red Book, the list of endangered animals, lists *38 species* and subspecies of birds which are threatened by extinction. Of these *not less than 31 either are parmanent residents of the coastal zone or migrate through our coast or establish temporary residence on our shores.* Rather than enumerate all these birds we will discuss the conditions of only three of these birds.

AN ENFORCEMENT OFFICER

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

The most famous member of the list is undoubtedly the *whooping crane*. The only flock of wild whooping cranes in the world (the last count revealed 57 birds) spends the winter months in the marshes and tidal flats in or around the Aransas National Wildlife Refuge. The whooping crane is a migratory bird which breeds in the expanses of the Northwest Territories in Canada. *The decline of the whooping crane was not due to hunting pressure but to destruction of habitat within most of its former range.* Surprisingly, the birds responded well to wise management and are slowly increasing in numbers.

The *brown pelican*, a clown of the bird world, was until the early 1950's a common sight along the Texas Coast. Beginning in 1956 and 1957 a drastic decline in the number of brown pelicans did occur and the population has not yet recovered from this downward trend. It is estimated that about 100 to 150 birds live along our coast. In the 1970 breeding season, they raised only nine young. The reason for the decline in brown pelican numbers *is difficult to pinpoint. There is good circumstantial evidence, however, that persistent pesticides of the chlorinated hydrocarbon family are to blame for the reduction of this species.*

Another bird, the *peregrine falcon*, a transient visitor to our coast is practically extinct. Contrary to the brown pelican, the reason for the reduction in peregrine falcons has been shown *conclusively to be the widespread use of DDT*, a persistent chlorinated hydrocarbon pesticide.

The plight of three bird species selected are indicative of the struggle wildlife faces in today's world. *Shrinking habitat* is a major cause for declining numbers. The introduction of *man-made poisons* into our environment, exemplified by the use of persistent insecticides, plays an important role in the decimation of wildlife species. In some cases it is difficult to pinpoint the exact cause of the decline of wildlife populations because the species reaches critically low numbers before the danger signal is recognized.

In addition to the bird species, the *red wolf* (Canis niger) and the *American alligator* (Alligator mississippiensis) are among those animals which are threatened with extinction. The exact status of the red wolf (some authorities do not recognize it even as a distinct species) is not quite clear. It appears to interbreed with the coyote and therefore shows a great variability in physical features. Although endangered, it is interesting to point out that until some two months ago Harris County offered a bounty on red wolves. Wolves are still unprotected in the state.

As of January 1, 1970, the American alligator is protected in Texas. The decline in numbers of the alligator has come about through habitat destruction and indiscriminate shooting and killing of the alligators. The success of the protection program cannot yet be evaluated. From reports I have, *extensive poaching still occurs and there is a lively black market for alligator hides.*

Effective protection of the species can only be accomplished by regulation of the market of articles made from alligator hide, such as shoes, purses, wallets and other articles of apparel.

CONFLICT OF INTEREST

It goes without saying that man and wildlife cannot coexist unless man makes a conscious effort to preserve habitat for wild animals and enacts laws forbidding the indiscriminate destruction of wild species. The latter is mainly a process of education and information.

Wildlife habitat must possess three elements to support wild animals. It must:

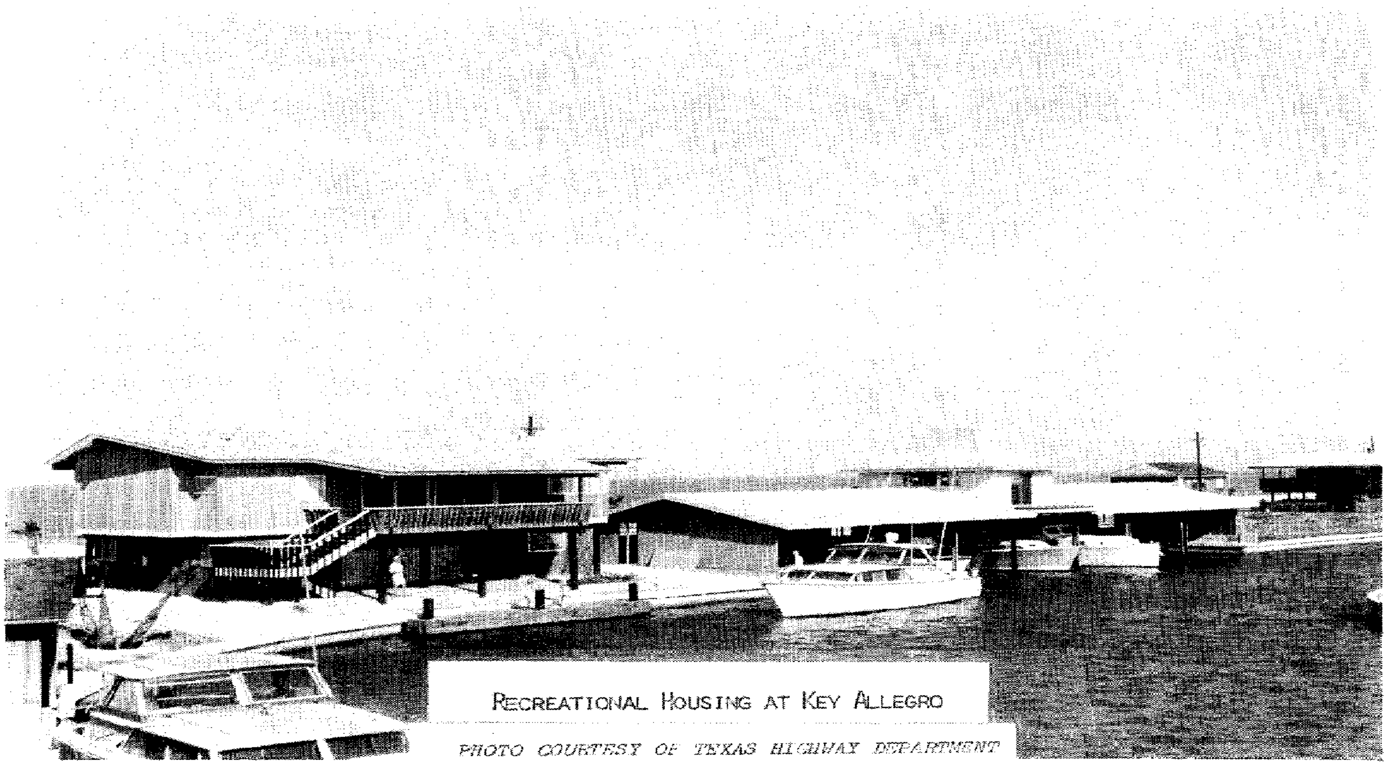
> *have an adequate fresh water supply,*
>
> *provide food,*
>
> *and offer cover where animals can seek protection from the elements as well as their enemies.*

On land these three requirements can be readily detected but in a marine environment such as a bay or estuary they are more subtle. The estuary is that zone where fresh water from a river meets the saline waters of the sea.

The river waters bring with them nutrients from the land in the form of inorganic salts containing phosphorous, potassium, and nitrogen, the three main fertilizer ingredients for plants. It is essential also that sunlight reaches and penetrates the water for without sunlight the intricate process of transformation of inorganic matter into life forms does not occur. In the presence of sunlight, green plants containing chlorophyll, change the carbon dioxide contained in the water or in the air into food stuffs which animal forms can utilize. These plant forms, from microscopic plankton on to sea grasses and aquatic plants, are the primary food source of the animals which inhabit our waters. Although many animals do not feed on plant material they depend on prey which derive their food from plants. *Therefore, destroy the plants and you eliminate all animals.*

Shelter in the estuary is afforded to the various prey species by the shallowness of the water into which the larger predators cannot follow. Also the shallow areas are effective in diluting the salt content of sea water and sunlight can penetrate the thin layers of water and provide an ample food supply.

Therefore the cutting off of fresh water influx into an estuary by daming a river most effectively chokes off one essential component in the delicate balance of the estuary.



Recreational Housing at Key Allegro

PHOTO COURTESY OF TEXAS HIGHWAY DEPARTMENT

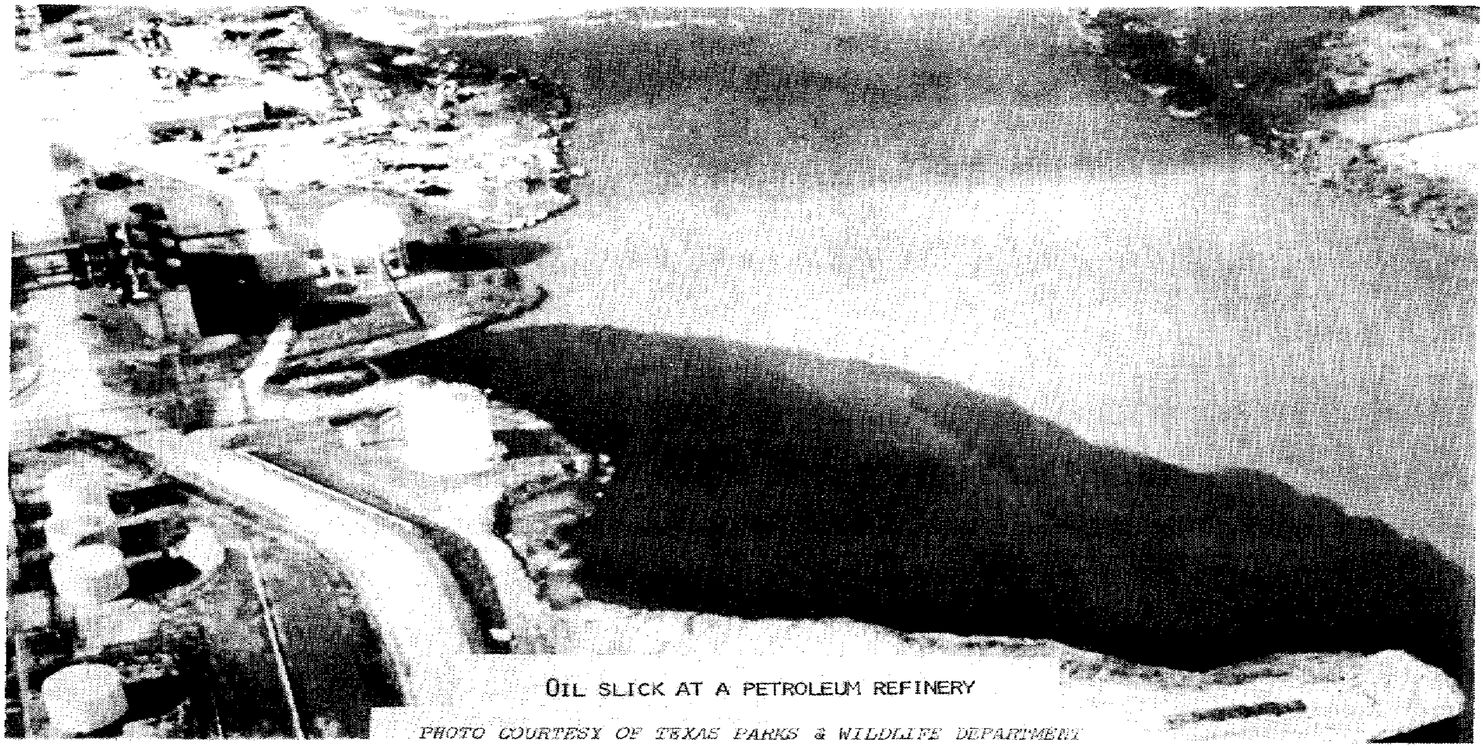
Estuaries and coastal wetlands (salt and fresh water marshes and algal mud flats) are also effectively destroyed by diking and filling to provide land for residential, industrial, or agricultural uses. The proximity to water is a great inducement for residential developments.

For esthetics and recreation man has always been attracted to land close to water and along the Texas coast we are witnessing the manifestations of this human trait. Although the conflict between municipal development and wildlife habitat has not yet reached crisis proportions on our coastal zone, *the time to plan in NOW in order to maintain suitable habitat for wildlife for the future.* Some developments on the lower coast illustrate the point. Key Allegro near Rockport destroyed a valuable nursery ground for marine species by filling and bulkheading a shallow bay area. Dredging boat channels and building up low land for home sites close-by effectively eliminated that area as wildlife habitat. On Padre Island extensive housing developments on both the north and south ends of the island have drastically changed the nature of these regions. A county park on the north end of Mustang Island eliminated the nesting grounds of a colony of seabirds: Sandwich Terns.

Similar but more extensive housing developments have occurred in the metropolitan areas of Houston and Galveston. Bolivar Peninsula northeast of Galveston is practically totally occupied by private homes.

These developments have been mentioned only to emphasize the need for careful long-range planning so that growth takes place in an orderly fashion and *assures the coexistance* of both man and wildlife species. *Without proper habitat preservation the most stringent protective regulations are valueless in maintaining a healthy wildlife population.* The timely establishment by the federal government of Padre Island National Seashore has reserved a large part of that island as a relatively unspoiled natural tract of land.

It also behooves the State of Texas to set aside certain areas where man is only a visitor and wild animal species have preference of occupancy. Areas suited as wildlife sanctuaries, especially for sea and shore birds, along our coast are the relatively inaccessible spoil islands and banks in Texas bays and lagoons. These islands were built up by deposits of spoil from dredging ship channels to ports, boat channels to oil wells or private developments, and the Intracoastal Waterway. *These islands are in the public demain; title to them is held either by the State of Texas or by the various port authorities.* Presently, many of these islands are used by various birds for nesting sites but conflicting human uses occur also. Among these can be listed: *dumping ground* for spoil from maintenance dredging operations (the principal function of these sites), *support for structures* used in the petroleum industry, *illegal dumping* of all kinds of refuse, and sites where *squatters* have erected cabins. Some of these cabins are utilized by commercial fishermen but the majority of the cabins serve as weekend shelters



OIL SLICK AT A PETROLEUM REFINERY

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

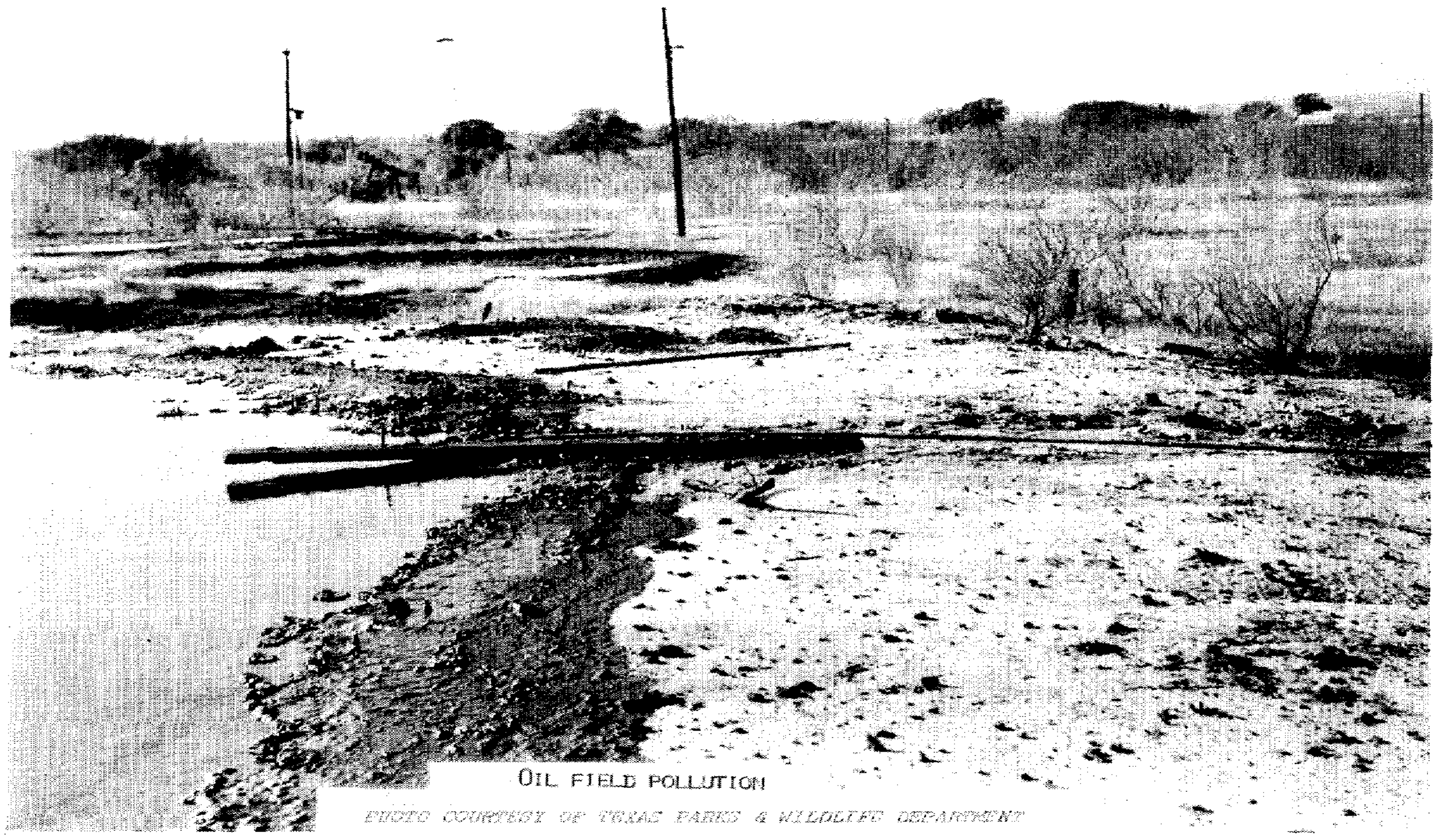
for sports fishermen. On some of the more extensive spoil islands regular little shanty towns have emerged. *Management of these islands should restrict their use as dumping grounds for spoil and nesting and roosting sites for birds. Human occupancy should be limited to primitive camping, and that only at such periods when the birds are not using them.*

Industries are locating more and more in the coastal zone. The proximity of water offers cheap transportation for raw materials and finished products alike, the open expanses of water to afford a ready-made disposal site for undesired by-products. Fortunately, man has recognized the need of wildlife for water unpolluted by industrial or municipal wastes and encouraging progress has been made in abating pollution. However, Texas still permits the discharge of oil field brine into estuaries and bays which demonstrably damage these areas as nursery grounds for marine species. The testimony presented by the Texas Parks and Wildlife Department at the Texas Railroad Commission hearing on November 4 and 5, 1970 in Austin, supports this statement. The amounts and the composition of the salts which make up oil field brine are quite different from the amounts and compositions of the salts found in seawater. Experiments by the Texas Parks and Wildlife Department are showing that oil field brine, free of oil, is toxic to marine organisms even when diluted with seawater.

Drilling operations for gas or oil in Texas bays are creating additional problems. The establishment of a well often necessitates the dredging of a channel and the spoil and silt derived from this operation may cover up feeding grounds for fish or water fowl. Also the channel changes patterns of ground currents within the bay and consequently affects the ecology of that area. Careful planning of drilling operations and locations of wells can greatly minimize the problems associated with the extraction of oil or gas.

Similarly, the *dredging for dead oyster shell* in Texas bays is affecting the biological balance in the bays. While dredging operations could be conducted in such a fashion as to minimize damage or even enhance the bay environment, present dredging practices in Texas are not conducive to these ends.

A healthy, live oyster reef requires for its maintenance an adequate supply of fresh water to dilute the salinity of seawater, for oysters can neither live in fresh water nor in sea water as found in the Gulf of Mexico. The water should be free of silt, because oysters are sedentary animals and cannot move from one spot to another in search of clear water. Silt settling on live oysters kills the animals. In addition, for the propagation of oyster reefs the freeswimming larval oysters (spat) must find a hard surface upon which they can settle to reach maturity. An excellent bottom for spat to settle upon are the small shell fragments occuring among the reefs which are being dredged up. These fines are unsuitable as aggregate for road construction but in Texas



OIL FIELD POLLUTION

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

find a ready market as raw material for cement manufacture. Therefore, in Texas dredging operations, even the small broken shell is commercially harvested.

This conflict of interest, which arises from the total extraction of dead oyster shell in preference to a continued harvest of live oysters, is hard to understand when one considers that Texas has an abundant supply of an equivalent or even superior substitute for oyster shell: *limestone*. Chemically limestone and oyster shell are made up of the same material: calcium carbonate. Large parts of Texas are giant fossil reefs or nearly pure limestone. The quarrying of limestone would have a much smaller adverse effect on wildlife habitat in the state than the dredging of oyster shell in the bays.

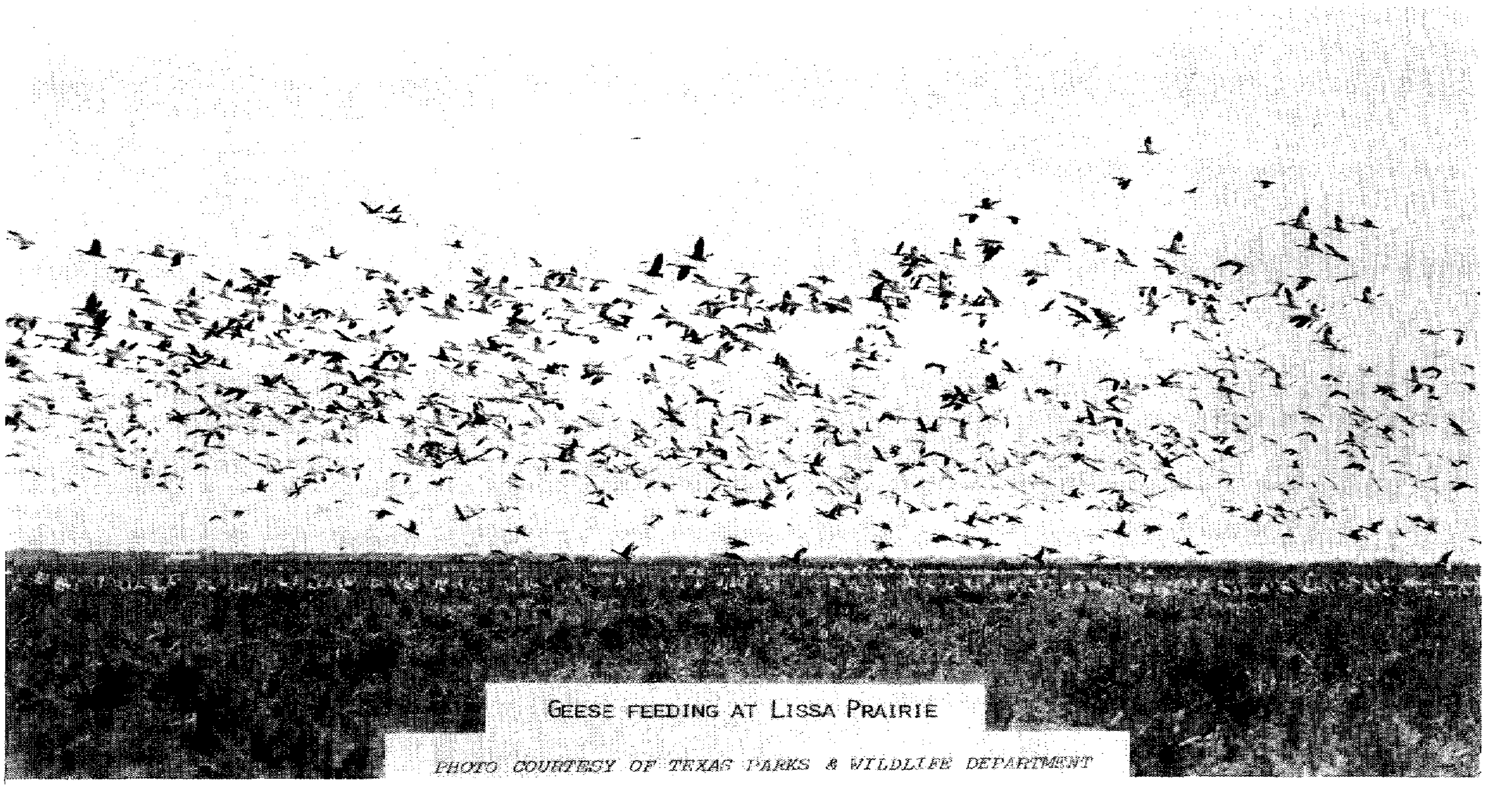
Most of the land in the coastal zone is under *agricultural use*. Some of the coastal marshes and the sandy soils of Kenedy and Kleberg counties as well as the grassy expanses of the barrier islands are used as ranch land. The heavier prairie soils are under intensive cultivation for the production of cotton or grain sorghum. Marshes on the upper coast where rainfall is more abundant have been converted to rice fields.

Ranching probably creates the least conflict between use of the land by man and wildlife habitat, provided overgrazing is carefully avoided, some cover for wildlife is maintained, and marshes are not drained. Cultivation of the land for agricultural crops, however, necessitates the clearing of the land with subsequent destruction of the native vegetation. In addition, agricultural practices today require the widespread use of chemical pesticides such as insecticides and herbicides.

The widespread use of *persistant chemical compounds* as control agents against insects or weeds poses a threat against wildlife species. Dramatic declines of populations of some wild species, such as the brown pelican, peregrine falcon, bald eagle and others, during the last few years have been related to the application of insecticides in agriculture. Persistant insecticides escape into the environment through land drainage, through air currents, during spraying operations, wind carried solid dust particles, co-distillation with water, and last, but not least, accidental spillage.

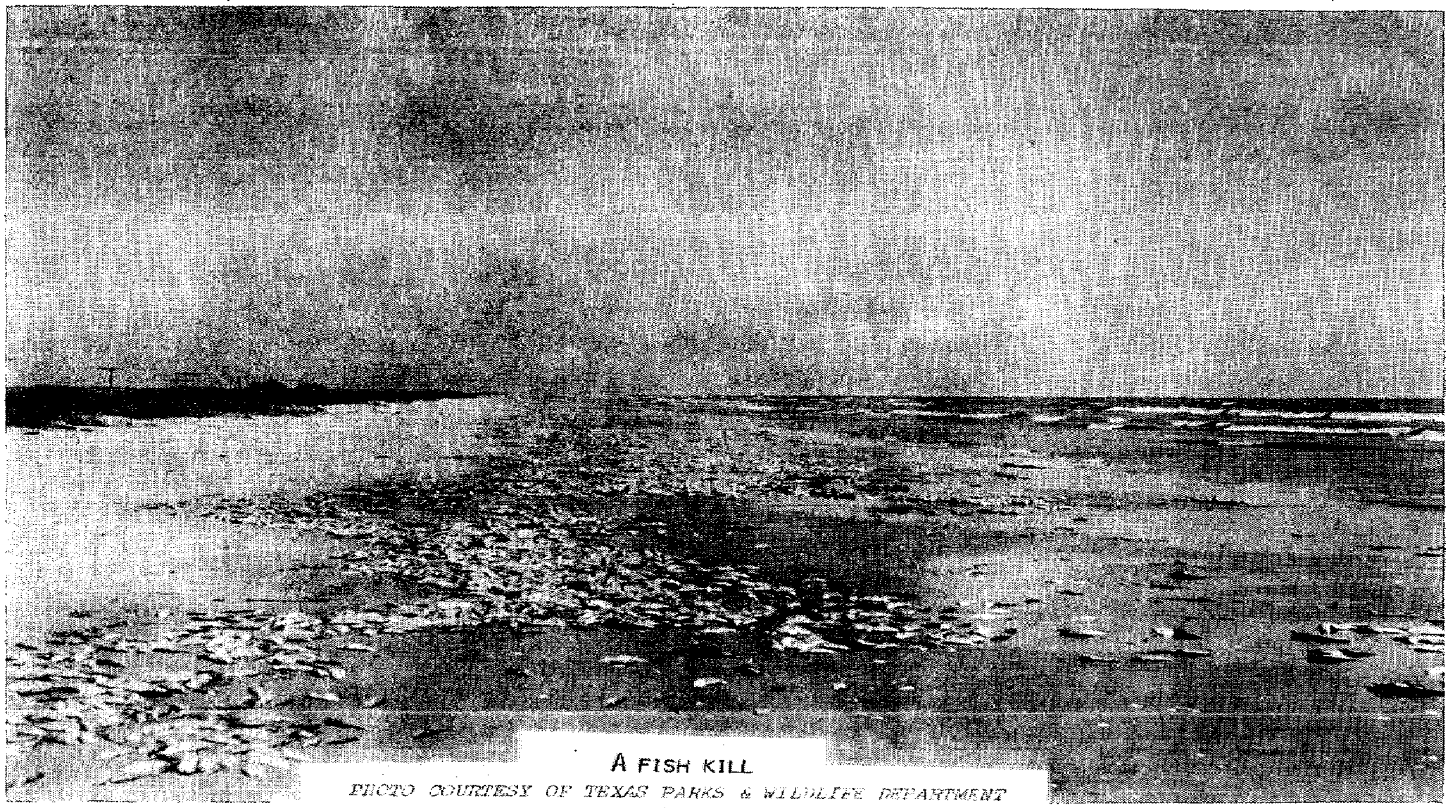
A meticulous and extensive study by the Texas Parks and Wildlife Department of juvenile trout populations in the lower Laguna Madre links the decline of this fish species with the use of the persistent insecticide DDT. The DDT entered the Laguna Madre environment through run-off from agricultural fields.

During the summer of 1970 in the rice fields of Brazoria County significant mortalities of fish and white-faced glossy ibises were observed. The white-faced glossy ibis is a marsh feeding bird which comes into the wet rice fields to feed upon the



GEESE FEEDING AT LISSA PRAIRIE

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT



A FISH KILL

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

many crustaceans and larval insects found in marshes and rice fields. Although no positive proof links these wildlife kills with insecticides the fish mortality occured after an application to the rice fields of Furadan (Carbofuran). This commercial insecticide loses its initially high toxicity two or three weeks after an application. In this instance, Furadan was sprayed inadvertently into a little creek which flowed into the bay. The dying white-faced glossy ibises showed symptoms of insecticide poisoning.

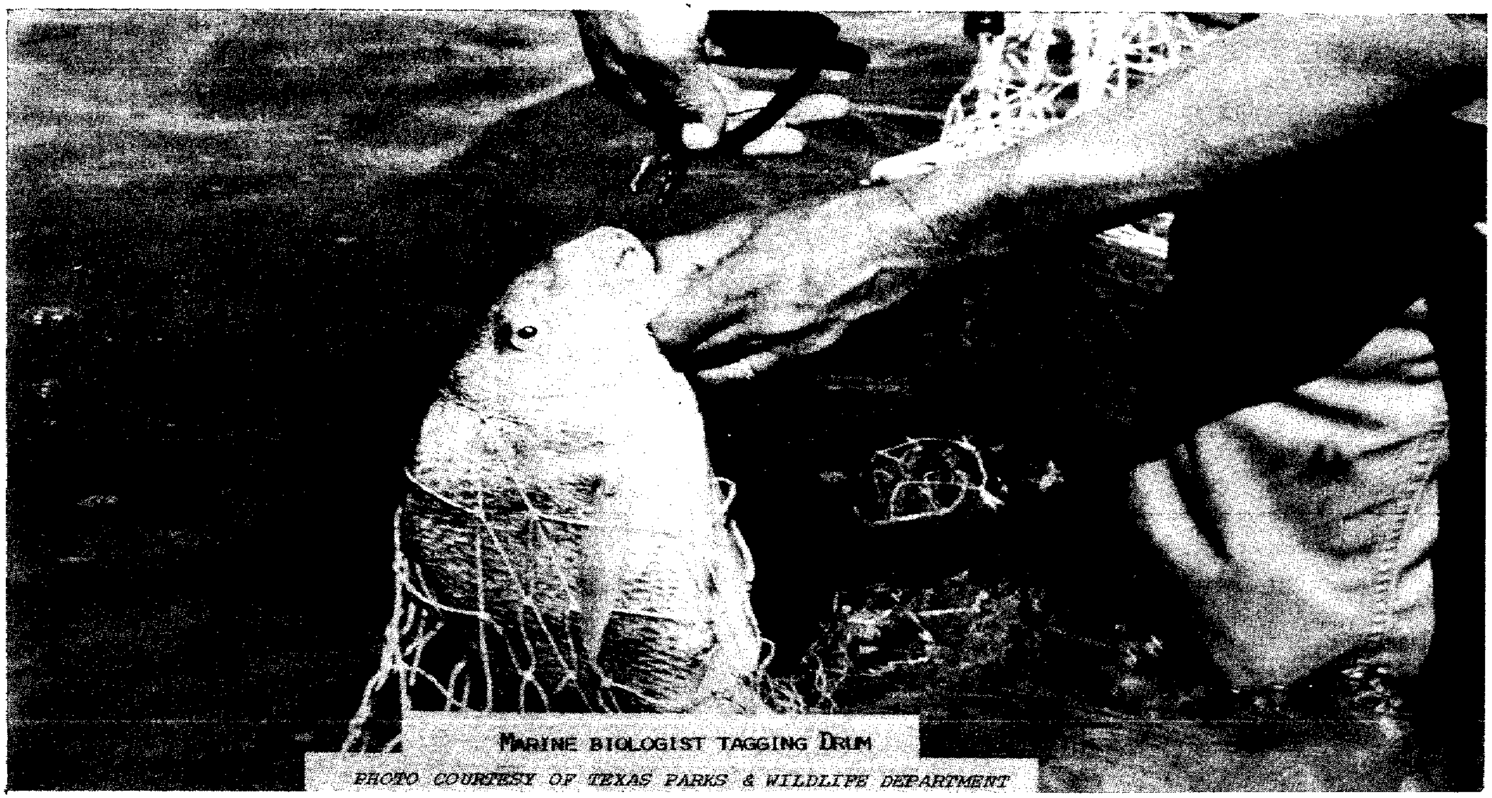
In the Guadalupe delta on Kamay Island and on Matagorda Island *diking and draining of wetlands* is taking place to provide improved pasture for cattle grazing. These wetlands have been in the past good habitat for birds. In these instances ranching is in conflict with wildlife by destroying suitable habitat.

Another conflict of interests exists in coastal counties which arises for *political reasons*. Six coastal counties: Chambers, Galveston, Refugio, Nueces, Kleberg, and Kenedy *are outside the regulatory authority* of the Texas Parks and Wildlife Commission. To more efficiently manage salt water fish resources in Texas greater flexibility in regulations is needed than is possible in non-regulatory counties. This is best illustrated in Kenedy County. In most summers in a section of the Laguna Madre called the "Hole" or "Graveyard" extensive mortalities - estimated at various times from a quarter to three-quarters of a million pounds or even higher - of marketable fishes occur. These fishes cannot be harvested by using troutlines and fishing rods before they succumb to rising salinity and oxygen deficiencies. *It seems ridiculous for game management officers TO ENFORCE present fishing rules so that most of these fishes may rot under the hot summer sun.*

Hunting or fishing do not seriously conflict with wildlife, provided regulations are adhered to. Limits should be obeyed and hunters must familiarize themselves with the huntable species to avoid killing protected species. *Also, hunters should be made aware of the intricate systems of checks and balances which makes life on this earth possible.*

As an illustration of this last statement one might consider the effect of predatory hawks upon the size of quail populations in proper habitat. Hawks DO prey to a limited extent on quail, but the main prey are rodents such as rats. The removal of hawks from an area allows the rat population to go unchecked and multiply freely. *Although rats do not prey on adult quail, they devour quail eggs, thus seriously endangering the quail population.*

Predators, contrary to widespread public belief, have a beneficial effect on wildlife species by keeping prey animal populations from increasing to such number that food becomes the limiting factor and many animals starve to death. *But before stravation of the prey animal sets-in, the vegetative cover of the land suffers severe damage.* The experience with the deer on the Kaibab plateau



MARINE BIOLOGIST TAGGING DRUM

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

in northern Arizona and with the elk herd on the Isle Royale on Lake Superior illustrate this predator-prey relationship.

In Texas through excellent management deer are again quite abundant. Because of climatic conditions this past fall, the range does not have the carrying capacity for the large deer population and biologists fear that many deer will starve to death. This possibility could have been avoided if enough deer would have been harvested by hunters during the season. Although bioligists recommend a heavy harvest, this goal was not attained because the system of hunting leases and doe permits in Texas gives the *landowner* effective veto power over directives of the Texas Parks and Wildlife Department.

An indirect effect of hunting on wildlife has been shown to exist for many years but recently has reached near crisis proportions. *In heavily hunted areas such as around duck blinds lead shot accumulates on bottoms of bays and ponds and many water fowl, especially mallards, are dying form lead poisoning due to swallowing of lead shot.* Hopefully, this problem will vanish in a few years by the replacement of the poisonous lead shot by non-poisonous soft iron shot.

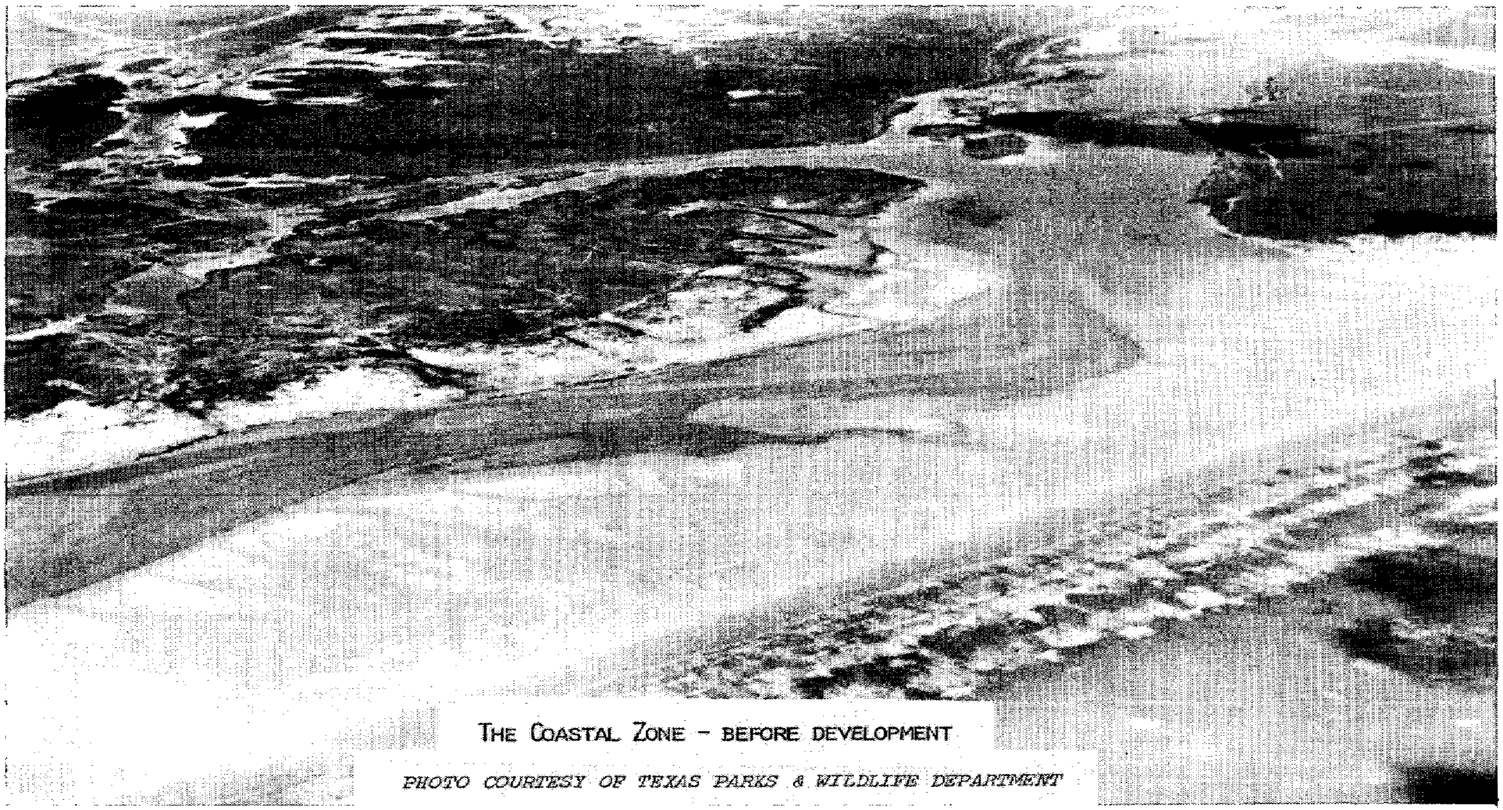
In the lower Laguna Madre, where *most of the world's* population of the redhead ducks winter, large numbers of these ducks are hooked on trotlines and are killed or mortally wounded. (C. A. McMahan and R. L. Fritz, Journal of Wildlife Management 31 (4), 783-787 (1967)). This unnecessary kill could be avoided by allowing commercial fishermen other methods of catching fish during the winter when ducks inhabit the Laguna Madre.

CONCLUSIONS

In general the status of wildlife in coastal Texas is in fair shape. When one considers only huntable species, such as deer, turkey and quail, the status should even be graded good. It is important to remember that deer especially are responsive to proper management and readily coexist in pastures together with cattle. Probably there are more deer today in Texas than at anytime in history. Waterfowl, such as geese and ducks, are decreasing in numbers because of habitat destruction in breeding and nesting areas.

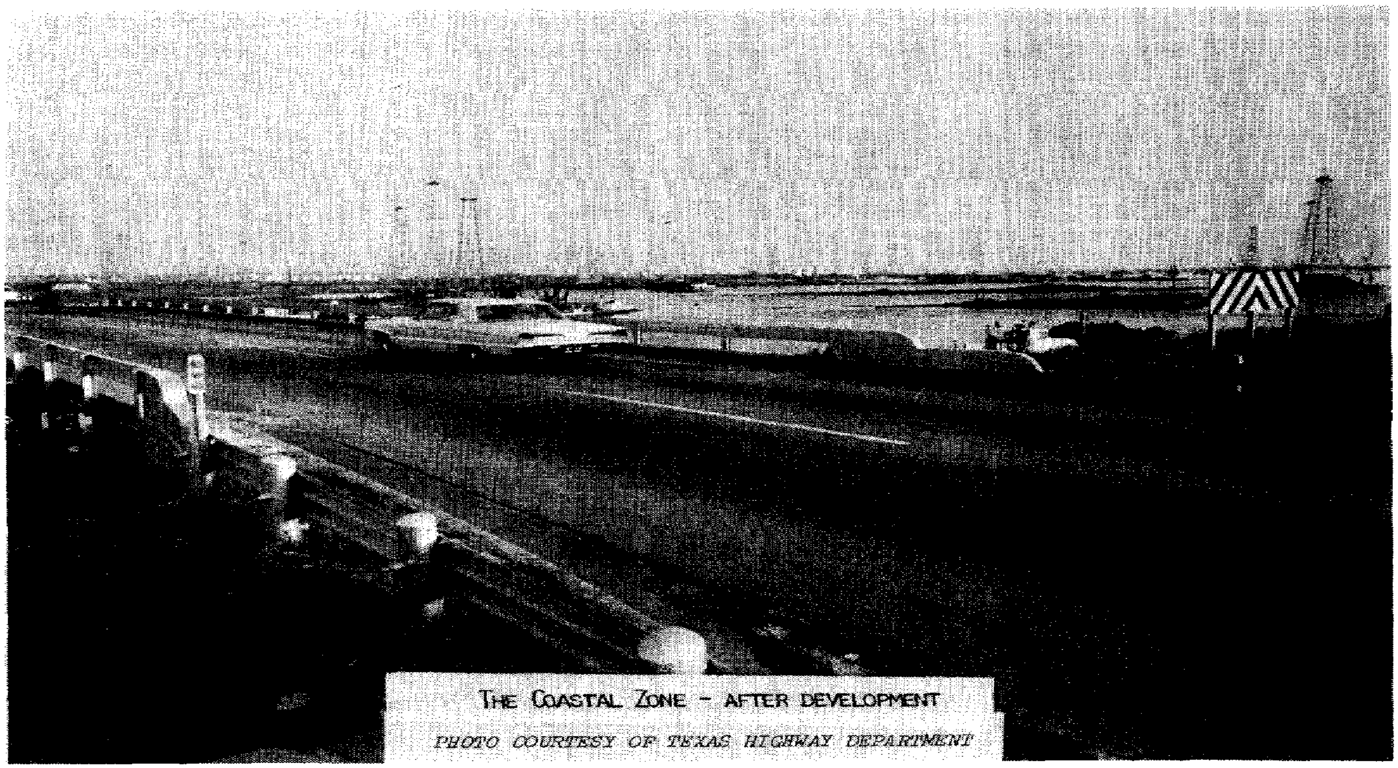
Judging from landings of finfish and shellfish, the fisheries industries seem better off than at any other time. *But to assess the true conditions of fisheries, population census of species must be used.* Landings are greatly influenced by such factors as demand, catching effort, and market price and, therefore, do not reflect the status of populations.

Many species of wildlife are still in existance in coastal Texas but their numbers have been greatly reduced since civilization reached the Texas Gulf Coast. Attwater's prairie chicken, a staple of the pioneers, exists only in isolated pockets. Sea turtles



THE COASTAL ZONE - BEFORE DEVELOPMENT

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT



THE COASTAL ZONE - AFTER DEVELOPMENT

PHOTO COURTESY OF TEXAS HIGHWAY DEPARTMENT once nested on South Padre Island, but not any more. Tarpons used to be caught in Texas bays, but their range today is restricted to the open Gulf.

A number of factors are responsible for the decline of truly wild species. All those factors are related to man.

One is often asked the question, "Why preserve wildlife?" The answer is a philosophical one and the noted American naturalist, John Muir (1838-1914), put it this way:

> WHEN WE TRY TO PICK OUT ANYTHING BY ITSELF, WE FIND IT HITCHED TO EVERYTHING ELSE IN THE UNIVERSE.

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TEXAS PARKS & WILDLIFE

THE STATUS OF PUBLIC HEALTH IN THE TEXAS COASTAL ZONE

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for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

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THE STATUS OF PUBLIC HEALTH IN THE TEXAS COASTAL ZONE

FOREWORD AND ACKNOWLEDGEMENTS

The present day status of public health on the Texas Gulf Coast is compounded by the rapid economic growth in that area. The great attraction of business and industry to the coastal region of our State *has caused not only a population increase, but a population shift.* With this influx of people have come public health and pollution problems, some of which are unique to this part of the State, and others common to all large population centers.

The purpose of this paper is to report the *existing public health conditions, both environmental and personal,* in the coastal region, with emphasis on the problems and problem areas. Attention is called to undesirable trends. The area being considered in this study includes the 36 counties lying within the five planning regions contiguous to the coast (Southeast Texas, Gulf Coast, Golden Crescent, Coastal Bend, and Lower Rio Grande Valley).

This report was prepared for the Coastal Resources Management Program, a program of the Governor's Office, Division of Planning Coordination, as part of the first phase of that office's Coastal Study. The information and material were obtained during personal interviews and from the files of the Texas State Department of Health and the Texas Water Quality Board. Grateful acknowledgement is made of the cooperation and valuable assistance given by our many friends on the staffs of those two agencies, and by the staff members of the Office of Comprehensive Health Planning.

SUMMARY OF PROBLEMS

Environmental Health

1. *Sanitary facilities* in recreation areas and mobile home parks are overburdened by a heavy influx of tourists and an increasingly transient society.

2. Proliferation of *small water and sewerage systems,* and inadequate local control of the use of septic tanks.

3. Overloaded and inefficiently operated *solid waste disposal sites,* and almost complete lack of procurement of future sites.

4. Incomplete coverage of the area by *mosquito control* districts and local health units.

5. Insufficient sanitary control of estuaries and contiguous land areas for protection of our *marine resources*, and insufficient regulation of the seafood production and processing industry (due to the lack of enabling legislation).

6. Lack of personnel to provide adequate inspection of *food handling and bedding manufacturing* establishments.

Personal Health

1. Lack of health care information and facilities for the *transient segment* - tourist and otherwise - of the population.

2. *High incidences* of tuberculosis and veneral disease, and a *lack of personnel* for an adequate case-finding and treatment program.

3. A lack of immunization and *family planning programs.*

I. INTRODUCTION

Health and pollution problems are "people" problems, and an analysis of recent census data and population trends quickly points out the reason for the health problems in the Texas Gulf Coast area. Almost one-third of the people in Texas live in this part of the State.

From 1960 to 1970 there was a 19% increase in population (Table I) in the 36 counties of the study area, as compared to a 14% increase in the statewide population. An interesting concentration-of-population phenomenon is shown graphically in Plate I. One half of the State's population lies on each side of the diagonal line for the year shown, and it is interesting to note that population concentration toward the coastal area in the last 10 years has made as much progress as it made in the preceding 30-year period. *About 3.4 million people, 31% of Texas' population, live on 33,200 square miles (36 counties), only 12% of the total land area of the state.* Expressed another way, there are *103 persons per square mile* in the 36-county coastal study area, and only *31 persons per square mile* in the rest of the state. So as not to be misleading, however, it should be pointed out that Harris County contains half of the population of the study area.

In the last decade, the Texas Coastal area has been overrun by a *highly transient segment of society - the TOURIST.* Sanitary facilities and health services programs to accomodate

TABLE I

POPULATION CHANGE IN THE

*COUNTIES IN THE COASTAL STUDY AREA**

County	1960	1970	Change	Percent Change
ARANSAS	7,006	8,468	+ 1,462	+20.8
AUSTIN	13,777	13,243	- 534	- 3.9
BEE	23,755	22,161	- 1,594	- 6.7
BRAZORIA	76,204	106,230	+ 30,026	+39.0
BROOKS	8,609	7,732	- 877	-10.2
CALHOUN	16,592	17,052	+ 460	+ 2.8
CAMERON	151,098	137,506	- 13,592	- 9.0
CHAMBERS	10,379	12,030	+ 1,651	+15.9
COLORADO	18,463	17,155	- 1,308	- 7.1
DEWITT	20,683	17,872	- 2,811	-13.6
DUVAL	13,398	11,364	- 2,034	-15.2
FORT BEND	40,527	51,410	+ 10,883	+26.9
GALVESTON	140,364	165,669	+ 25,304	+18.0
GOLIAD	5,429	4,580	- 849	-15.6
HARRIS	1,243,158	1,722,533	+479,375	+38.6
HIDALGO	180,904	173,715	- 7,189	- 4.0
JACKSON	14,040	12,597	- 1,443	-10.3
JEFFERSON	245,654	242,719	- 2,940	- 1.2
JIM WELLS	34,548	32,127	- 2,421	- 7.0
KENEDY	884	665	- 219	-24.8
KLEBERG	30,052	32,181	+ 2,129	+ 7.1
LAVACA	20,174	17,483	- 2,691	-13.3
LIBERTY	31,595	30,565	- 1,030	- 3.3
LIVE OAK	7,846	6,308	- 1,538	-19.6
MCMULLEN	1,116	992	- 124	-11.1
MATAGORDA	25,744	27,630	+ 1,856	+ 7.2
MONTGOMERY	26,839	46,950	+ 20,111	+74.9
NUECES	221,573	233,965	+ 12,392	+ 5.6
ORANGE	60,357	70,380	+ 10,023	+16.6
REFUGIO	10,975	9,089	- 1,886	-17.2
SAN PATRICIO	45,021	44,445	- 576	- 1.3
VICTORIA	46,475	52,776	+ 6,301	+29.3
WALKER	21,475	24,885	+ 3,410	+15.9
WALLER	12,071	13,965	+ 1,894	+15.7
WHARTON	38,152	36,128	- 2,024	- 5.3
WILLACY	20,084	15,432	- 4,652	-23.2
TOTALS	2,885,021	3,440,002	+554,945	+19.2
STATEWIDE	9,728,783	11,112,497	+1,383,714	+14.2

NOTE: It is interesting to note that 21 of the 36 counties lost population. Harris County accounted for 86% of the total gain for this coastal region, and Harris and Montgomery Counties together accounted for 90% of the total increase.

**U. S. Bureau of the Census preliminary releases (August, 1970.)*

this group are overburdened. Litter on the beaches, shallow water supply wells, and often inoperable and undersized sewerage facilities (if any) are characteristic of the inadequacies. The tourist is the least informed person in our midst; does he know where to go for medical help? What facilities do we have to serve him while he is in our area?

In providing for the transient segment of our society, tourist or otherwise, one important consideration is the matter of *mobile housing*, the available space for these homes, and the related sanitary facilities to serve them. The September 15, 1970 issue of the Texas Municipal League newsletter Legislative Policymaking Facts states that as of March, 1970, there were *90,474 mobile homes* registered with the Texas Highway Department, an increase of almost 23,000 since last year. Roughly *34%* of that increase occurred in the coastal study area (this area comprises only 14% of the 254 counties in Texas but 31% of the population). In 1969, *more than 70%* of the new homes sold in Texas for less than $15,000 were of the mobile type; and nationally, 48% of all single family homes sold were of this type. This year, mobile home sales will comprise *more than 95%* of all home sales under $15,000.

The coastal region is also becoming a *very popular retirement area;* another reason for increasing population. An integrated program of geriatric centers and services will be needed. At the present time, there are no organized centers, and such services are handled on a more or less random basis. The greatest need for geriatrics is a motivation and remotivation program.

Although the state regulatory and advisory agencies - primarily the Texas State Department of Health - have carried on active surveillance programs and have appropriately notified local officials of the various problems and hazards, there has generally been *inadequate environmental health planning at the local level and heed taken of these warnings in this part of the state.* The coastal area is an important food source, both land and estuary, as well as an expanding industrial area. It is the drainage basin for the entire state, and it needs constant sanitation surveillance, more than any other part of the state, because of the subtropical climate; it is a prime area for reinfection. *Diseases* like plague, dengue, yellow fever, and malaria - nonexistent at present - could be reintroduced through the shipping industry because the vectors (flies, fleas, mosquitoes, rats) are still there.

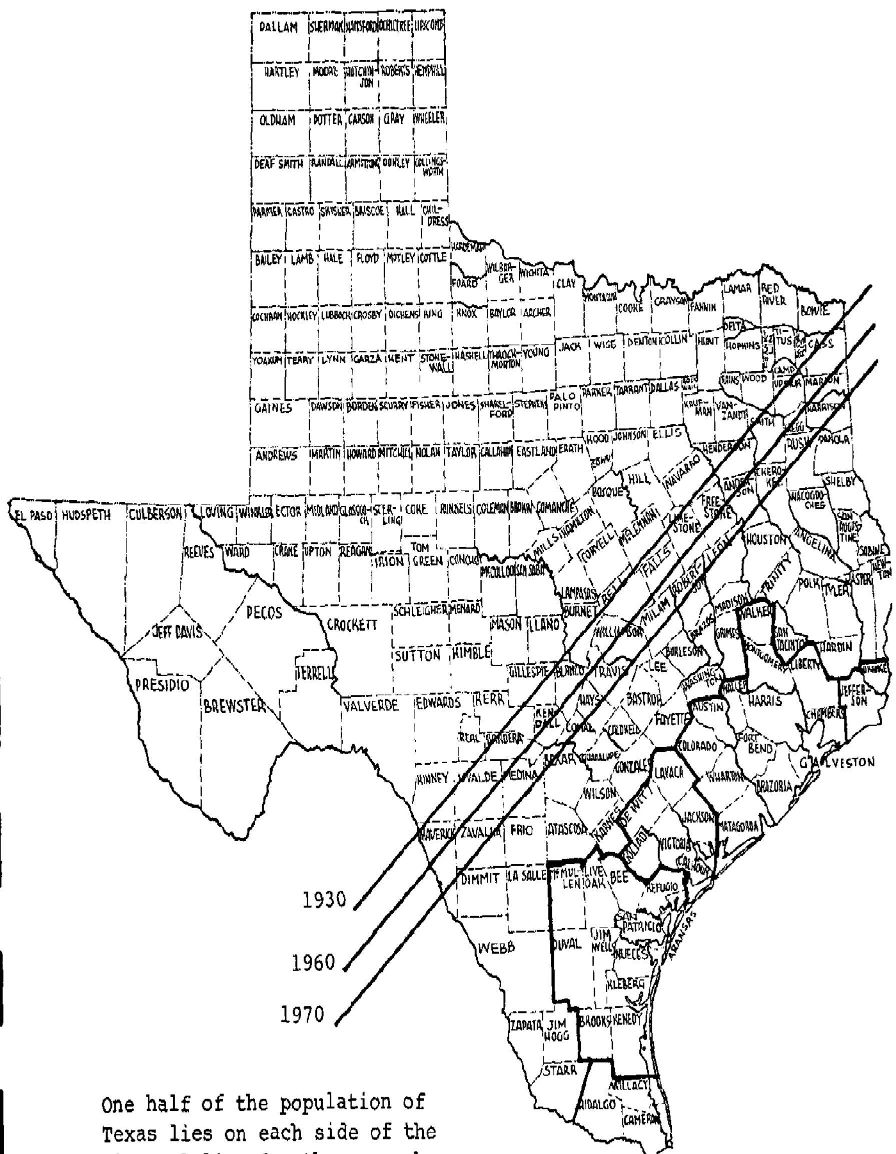
II. ENVIRONMENTAL HEALTH CONSIDERATIONS

Water Supply

There are about 550 water supply systems (Table II) in the study area, over 200 of which are located in the Houston metropolitan and suburban areas. The "spawning" of these systems,

PLATE I

POPULATION DISTRIBUTION



One half of the population of Texas lies on each side of the diagonal line for the year shown.

made possible by the availability of an abundance of good quality ground water, has occurred in Harris and adjacent counties, especially Montgomery County. *Consolidation of these systems - a master system - is needed in this area,* and will increase public health protection. This can be accomplished by the large public water systems extending services to adjacent small communities.

Approximately *25% of the systems in these 36 counties* hold the Texas State Department of Health State Approval status. Absence of "State Approval" does not necessarily mean that the water is unsafe, but it can be interpreted as an indication of the amount of time devoted to operation of the system. State Approval indicates not only good quality water, but operator competence and safisfactory operation and maintenance. The related fact that there are not enough properly trained water utilities personnel to oversee the management of the numerous small water systems (less than 5,000 population) points to the long-time problem of *public apathy* and a frequent unwillingness on the part of many city officials to pay for good operation and maintenance, i.e., better salaries for competent personnel. This is a problem mainly with the systems serving populations of less than 5,000.

Sewerage - Water Pollution

In general, the Texas coastal waters are satisfactory for fishing and recreation. Water oriented recreation, including water contact sports, is a desirable use of the waters of the state everywhere. Water contact activities in natural waters are not opposed by the state health agency where routine sanitary surveys support such activities, and where, in addition, as a flexible guideline to be used in the light of conditions disclosed by the sanitary survey, the geometric mean of the number of fecal coliform bacteria is less than 200 per 100 milliliters (ml.), and not more than 10% of the samples during any 30-day period exceed 400 fecal coliform bacteria per 100 ml. This policy is advisory only and in no way limits the responsibilities and authorities of local health agencies.

One has to marvel at *Nature's self-purifying capability* and assimilative capacity when analyzing the fact that *two-thirds of the 368* wastewater treatment plants in the coastal area (see Table II), most of which discharge eventually to the estuaries, *are producing a poor quality effluent.* Over 150 of these plants are located in and around Harris County (147 in Harris County, about 50 of these within the Houston city limits), and the same problem is being experienced with proliferation of small systems as was mentioned for water supplies above. The *wastewater plant problem,* however, is of a more critical nature.

In addition to this matter, the exposure to effluent from *septic tanks* presents a potential public health hazard in the coastal region. Soil conditions are generally unsuited for proper septic tank operation; the effluent standing in roadside ditches provides excellent breeding places for mosquitoes; in some locations, the bacteriological quality of ground water is endangered; there is continual exposure of people to the effluent in many areas; in most locations, there is *little or no* regulation and control of these individual disposal systems at the county level. These facts have furnished the basis for Texas Water Quality Board action in passing several septic tank control orders.

The construction of community sewerage systems in the smaller urbanized areas will eliminate or greatly reduce septic tanks and the health hazard they pose. Prior planning for the development of regional sewerage systems and integration of the small urban areas into such systems will be a significant step forward toward solving health and pollution problems.

Solid Waste

The Texas State Department of Health made a statewide survey in 1968 of all the domestic solid waste disposal sites in Texas. Only *4.7% (40 out of 875)* of the sites surveyed were acceptable sanitary landfills. In the coastal study area, the record is not much better (see Table II); 15 out of 171 (8.8%) are acceptable.

The survey pointed out several problems, most of which are not unique to any particular area, but apply statewide:

1. The *people's attitude* toward a "dump" site, i.e., land use incompatibility, is unfortunate.
2. *Flies and rodents*, dust and odors, smoke from open burning.
3. *High watertable* - common in the coastal zone - leaches contaminants and pollutants out of the garbage into ground water supplies.
4. *Manpower;* a strike would pose an immediate public health problem.
5. It is very difficult to attract sufficient numbers of *qualified personnel* to this field of work.
6. Poor waste disposal programs in *recreational* areas.
7. *"Promiscuous" dumping*, i.e., into roadside ditches.
8. Lack of *financial and administrative* structure and resources.
9. Lack of *planning* by counties and local entities.

Suggestions for solutions and improvements of the general situation:

TABLE II

ENVIRONMENTAL CONTROL SYSTEMS

TEXAS COASTAL REGION

County	Wastewater Treatment Plants: Number	Wastewater Treatment Plants: Satisfactory Operation	Water Systems: Number	Water Systems: State Approved	Solid Waste Disposal Sites: Number	Solid Waste Disposal Sites: Sanitary Landfill
Aransas	3	1	7	1	2	0
Austin	4	3	4	2	2	0
Bee	4	1	2	1	3	0
Brazoria	16	5	25	8	15	0
Brooks	1	0	1	1	1	0
Calhoun	5	3	5	3	3	0
Cameron	11	5	22	6	8	1
Chambers	5	1	9	3	3	0
Colorado	4	3	6	3	6	0
DeWitt	5	1	5	2	3	0
Duval	3	1	5	1	3	0
Fort Bend	14	5	11	4	6	1
Galveston	20	4	29	11	10	0
Goliad	1	1	1	1	1	0
Harris	147	40	200	23	19	5*
Hidalgo	12	9	23	11	12	1
Jackson	4	2	4	2	3	1
Jefferson	21	7	18	6	5	1
Jim Wells	3	2	3	3	3	0
Kenedy	0	-	1	0	1	0
Kleberg	2	1	4	2	3	0
Lavaca	3	3	3	3	3	0
Liberty	7	2	16	3	5	0
Live Oak	2	1	5	1	2	0
McMullen	0	-	2	0	1	0
Matagorda	6	2	15	2	3	1
Montgomery	4	1	31	1	2	0
Nueces	16	4	10	4	8	3
Orange	10	5	29	4	6	0
Refugio	3	1	5	2	4	0
San Patricio	8	2	11	6	8	0
Victoria	5	2	6	2	4	1
Walker	5	1	5	1	2	0
Waller	5	2	3	3	4	0
Wharton	7	4	6	3	4	0
Willacy	2	1	8	1	3	0
TOTALS	368	126	540	130	171	15
Percent		34.2		24.1		8.8

*one incinerator

1. *Public education programs* to obtain acceptance of solid waste management programs, publicize the urgent need for proper systems, encourage planning at the local level, and encourage competent people to enter the field.

2. Provide *better training* for all personnel in the solid waste profession.

3. *Upgrade the profession* and raise the status and image of the workers by setting higher standards for qualification and performance, better pay, and better working conditions.

Much of industrial solid waste, which is under the regulatory jurisdiction of the Texas Water Quality Board, is in aqueous suspension or in semi-liquid form, and has not presented a significant problem as solid waste.

Vector Control

Of the common vectors - fly, rat, tick, flea, mosquito - *only the mosquito* constitutes a significant public health hazard in the coastal region. The other vectors are usually controlled indirectly through adequate control and management of other environmental problems, i.e., flies as a part of the sewerage and refuse problem, rats - usually - as part of the refuse problem, ticks and fleas as part of the control of rats and other animals. While rats are often controlled as part of the refuse program, most large cities have separate, active rodent control programs in operation.

The mosquito, which is of great concern in the coastal region, is, for the most part, a *nuisance*. But this insect is also responsible for periodic outbreaks of *encephalitis; yellow fever*, another mosquito-transmitted disease, has been nonexistent in Texas, and *malaria* has been rare in recent years. It is not known, however, how many secondary infections are the result of mosquito bites, or how significant a problem the mosquito is in recreational areas - how many people go home just to get away from the nuisance?

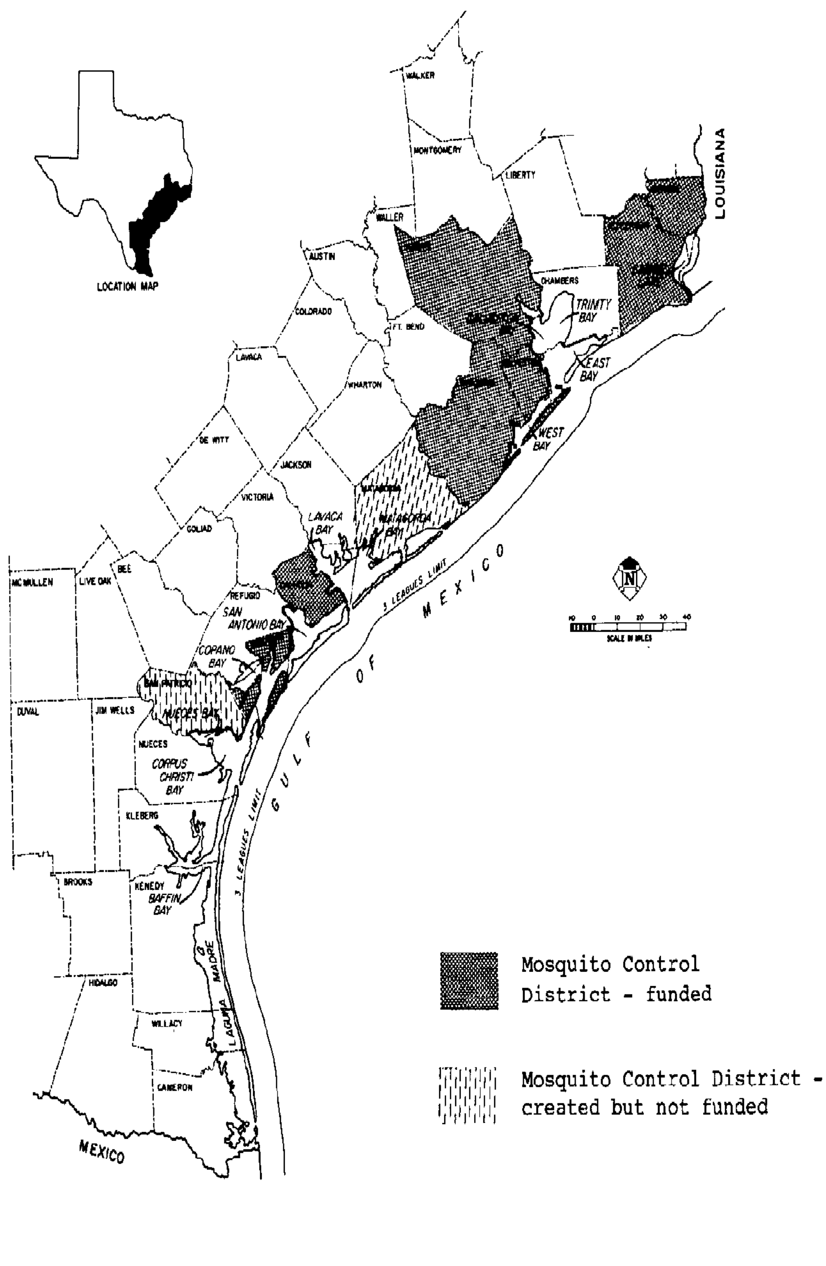
For effective control, *every county should have or be part of a mosquito control district.* There are only seven funded districts in the coastal area at present (see Plate II); such districts are especially needed from Kingsville to Refugio and in the Rio Grande Valley, although during the summer cotton spraying, the density of mosquitoes in the Valley area is not great.

Pesticides

Even with our best control efforts, *insects still destroy about one-fourth of everything we raise.* The organophosphate

PLATE II

MOSQUITO CONTROL DISTRICTS



insecticides are the most common ones used in Texas agriculture today; few farmers use DDT, and few have found it useful since about 1950. So if DDT were banned in Texas, it would not have a significant effect on our agricultural program. It is interesting to note that Sweden, the first country to ban DDT, *is not ready to return* to the use of this material becuase the pine weevil is threatening to wipe out the country's forests. Likewise, the *use of DDT is being reactivated* on the island of Ceylon because of *one million cases of malaria* in the last several years of the ban.

In the lower Rio Grande Valley, since 1964, occupational exposure to organophosphate insecticides has resulted in a significant number of cases of *acute poisoning* (over 300 cases). All cases have been successfully treated with no known residual effects. It appears that as the workers gain knowledge of the hazards and experience in handling the materials, the number of cases declines.

The hazards involved with the use of pesticides can be summarized as follows:

1. Acute poisoning cases

2. Possible contamination of potable water (short term)

3. Possible runoff of contaminants (NOTE: DDT is highly toxic to fish, although *toxaphene* is the chemical most commonly involved in fish kills in Texas; DDT is highly insoluable in water, i.e., soluable only to the extent of about 1 ppm.)

4. Environmental buildup. The long term effects on the ecology are not completely understood, but they are apparently not critical.

Some of the hazards of not using certain pesticides are as follows:

1. The entire coastal area is very receptive to an array of *vector-borne diseases*.

    a. Malaria and dengue, which were once prevalent in that area, could be reintroduced

    b. Plague, related to introduction of infected rats and fleas

    c. Murine typhus (flea-borne)

    d. Encephalitis, the most likely vector-borne disease to occur in the coastal area

2. Heavy *crop damage*

In contemplating the ban of a particular insecticide, therefore, one must take into consideration the Risk-Benefit Equation and assign priorities. *How much risk are you taking for the amount of benefit derived?*

Marine Resources

A great potential exists in the Texas Gulf Coast's *ability to produce seafood.* In general, the Texas bays and estuaries are in good condition, and the acreage open to oyster harvesting has remained relatively constant in most of the bays for the past 20 years. Lavaca and Galveston Bays are the exceptions. Approximately *54% of Lavaca Bay* (see Plate III) is closed to harvesting because of sanitary (8,500 acres - urban runoff) and industrial (11,400 acres - recent mercury findings) hazards. On the other hand, Galveston Bay, from whence come 75 to 90% of the Texas oysters, has been significantly "enlarged" in approved acreage (55,565 *additional acres* in Galveston Bay proper between 1951 and 1969). This has been due to improved surveillance techniques, as well as more information available regarding the condition and characteristics of the bay.

The bays and estuaries are not free of environmental hazards, however. Some of the more pressing problems/threats are:

1. *Increasing population and industrialization*

2. Large quantities of *domestic wastewater* placing a heavier organic burden on the assimilative capacity of the coastal waters.

3. Rapid changes in technology are creating new waste disposal problems and, in turn, a need for additional emphasis on *monitoring of industrial waste discharges.*

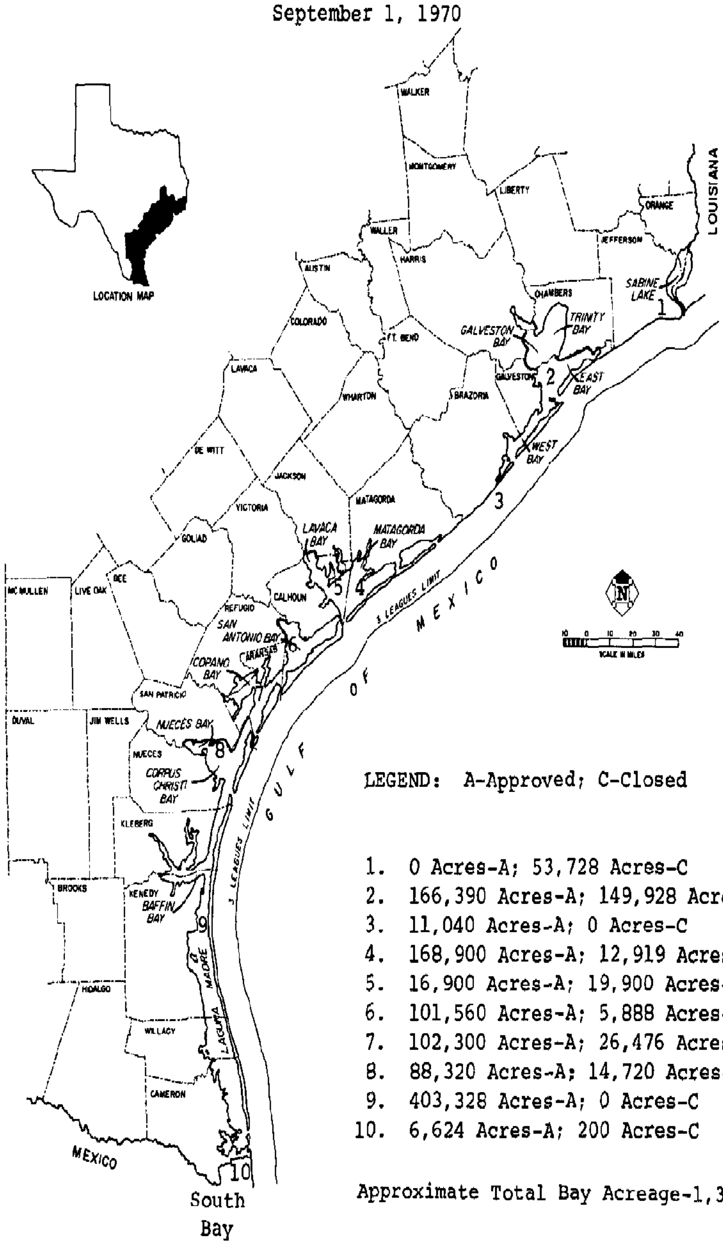
4. *Heavy metals,* such as mercury (brain, kidney, and nervous system damage), cadmium (cardiovascular disorders), and lead (miscarriage, damage to vital organs).

While there is specific legislation covering the oyster and crab processing industry, there is no "Wholesome Food Act" that places the *same emphasis* on regulation of seafood processing as on red meat. *There is little or no specific control,* for example, over the rate of moving marine produce from boat to processing plant, particularly in the case of the "small" operators, with the exception, of course, of that exercised over oysters and crabs. Marine produce is highly perishable and, therefore, requires special handling procedures and techniques between time of harvesting and time of processing.

At the plant, disposal of liquid and solid processing waste is a problem, and in general, there is *no satisfactory means of disposal provided.* The ill-planning of dock facilities has presented

PLATE III

MARINE RESOURCES - OYSTER HARVESTING
Texas State Department of Health
September 1, 1970



LEGEND: A-Approved; C-Closed

1. 0 Acres-A; 53,728 Acres-C
2. 166,390 Acres-A; 149,928 Acres-C
3. 11,040 Acres-A; 0 Acres-C
4. 168,900 Acres-A; 12,919 Acres-C
5. 16,900 Acres-A; 19,900 Acres-C
6. 101,560 Acres-A; 5,888 Acres-C
7. 102,300 Acres-A; 26,476 Acres-C
8. 88,320 Acres-A; 14,720 Acres-C
9. 403,328 Acres-A; 0 Acres-C
10. 6,624 Acres-A; 200 Acres-C

Approximate Total Bay Acreage-1,349,121 Ac.

special sanitation problems, such as inadequate or no toilet facilities, inoperable or lack of backflow preventors, and inadequate facilities for washing boats and equipment.

At the present time, control of these aspects of the marine produce industry, by the Texas State Department of Health, would be greatly strengthened by the passage of legislation that would set forth definitive requirements and authorize the development of specific regulations.

Food and Milk

Food contamination by insects and rodents and subsequent spoilage is an especially critical matter in the coastal zone. This is the Number One food control problem in the state, and is *magnified in the coastal area by the climatic conditions.* Closer control is needed because the food originating in this area (mostly fish) is of a more perishable nature.

Approximately 50% of the shrimp breeding in the world is accomplished in the Texas coastal zone, and activities related to this industry - control of bacterial contamination - constitute a sizeable portion of the Texas State Department of Health's Food and Drug Division surveillance effort. *This particular program needs about twice the staff* to sufficiently do the job.

The coastal region is *not* a good dairying area; there are very few dairies located there, and consequently, no problems of major importance. Pasteurization has, for the most part eliminated milk-borne diseases. Many of the cities have their own milk inspectors, which has resulted in some duplication of effort with the Texas State Department of Health. Updating of laws and regulations would eliminate some of this overlap and permit the more efficient and effective utilization of personnel.

Bedding

This program of the Texas State Department of Health protects the public health by regulating the processing and manufacture of bedding material and products, and the processing and sale of second hand material and products. The big problem is the regulation (and there is considerable *illegal* activity in this field) of the sale of the *second hand bedding*. It must be germicidally treated to be rendered safe for resale. This problem is unique to a Texas coastal location (Houston) only in that there are more bedding manufacturers, processors, and related activity in that area (Dallas is second behind Houston).

The solution is more people for regulation and enforcement activities, but funds are not available for a larger staff. The bedding program is unique in that, by law, it must be *fiscally self-sustaining* through the requirements for registration fees and revenue inspection stamps. It gets no revenue from the General Fund.

Radiation

In general, the production and use of radioactive materials in Texas does not pose a threat to public health. However, there is a significant potential for such a hazard if the program of constant surveillance carried on by the Texas State Department of Health's Division of Occupational Health and Radiation Control is not maintained. About 50% of all the licensees in the State of Texas are issued to users in the coastal region; 80% of this number (40% of the total) is located in Harris, Galveston, and Jefferson Counties.

The *industrial and medical utilization* of radiation equipment and sources seems to be concentrating in the coastal area. It is more economical to serve large numbers of people with the more sophisticated and expensive devices, and this equipment is being "drawn" to the dense coastal population centers from other parts of the state. The area is enhanced by a large potential in the Coastal Bend region for mining low grade uranium ore. A "glamorous" part of the surveillance effort is centered around Tood Shipyards on Pelican Island, Galveston, Texas, where the *nuclear ship Savannah* is serviced and refueled.

One of the main problems encountered in the radiation control program (a problem not especially common to any particular area) is that of obtaining the cooperation and compliance of industrial radiographers. In general, this somewhat transient group of people is careless about instrument calibration and the use of proper safety equipment.

At the present time, the Texas State Department of Health is adjusting its program to deal with a new hazard: *Non-ionizing radiation produced by electronic sources,* laser and microwave devices, and radar. This situation is characterized by improper shielding and defective components, and can be remedied, for the most part, by stricter standards governing the manufacture of the equipment. There has been a legislative proposal to expand the definition of radiation, which would give the State health agency legislative authority over these radiation sources.

Air Pollution

Because of the high concentration of population and industry, and the unique meterology of the area, the Texas Coastal Region has the greatest potential for the occurrence of air pollution problems. The area is characterized by rapid heating and cooling of the land surface, updrafts during the day, and downdrafts at night. The localities of prime concern are the Houston-Galveston area, Beaumont-Port Arthur-Orange area, and Corpus Christi area to some extent.

Air quality may have some effect on respiratory disorders such as emphysema and chronic bronchitis, but it has been determined to have *no effect* on tuberculosis. *Some investigators are not convinced of the relationship* between air pollution and respiratory diseases.

Occupational Safety

Although accidents certainly are not unique to the coastal area, most of the effort of the State Health Department's Occupational Safety Program (related to the work of the Occupational Health Program) is concentrated in this region because *the majority of the industrial activity in the State is found there.* The "heavy" areas are Houston, Beaumont-Port Arthur-Orange, Corpus Christi, and the Rio Grande Valley. Dallas-Fort Worth and San Antonio run a close second.

Plate IV indicates the high-accident areas of the State, and is based on numbers of "debit employers." A debit employer is one whose accident experience (record) is worse than the average for his type of industry.

Housing

Housing has an undisputed and profound effect on our daily lives. This matter is not reserved for the poor, but is of concern to all of society. When considered in relation to the environment, housing is usually seen in context with "public" housing for the "economically deprived," or is related to "substandard" conditions. Certainly, many of the problems confronting mankind in his environment - disease, maternal and infant mortality, juvenile delinquency, drug abuse, truancy, sanitation - could be ameliorated by providing and maintaining satisfactory housing. This paper considers the more direct environmental and personal health problems, many of which can be related to housing, rather than placing emphasis on housing problems in the Coastal Area.

III. PERSONAL HEALTH CONSIDERATIONS

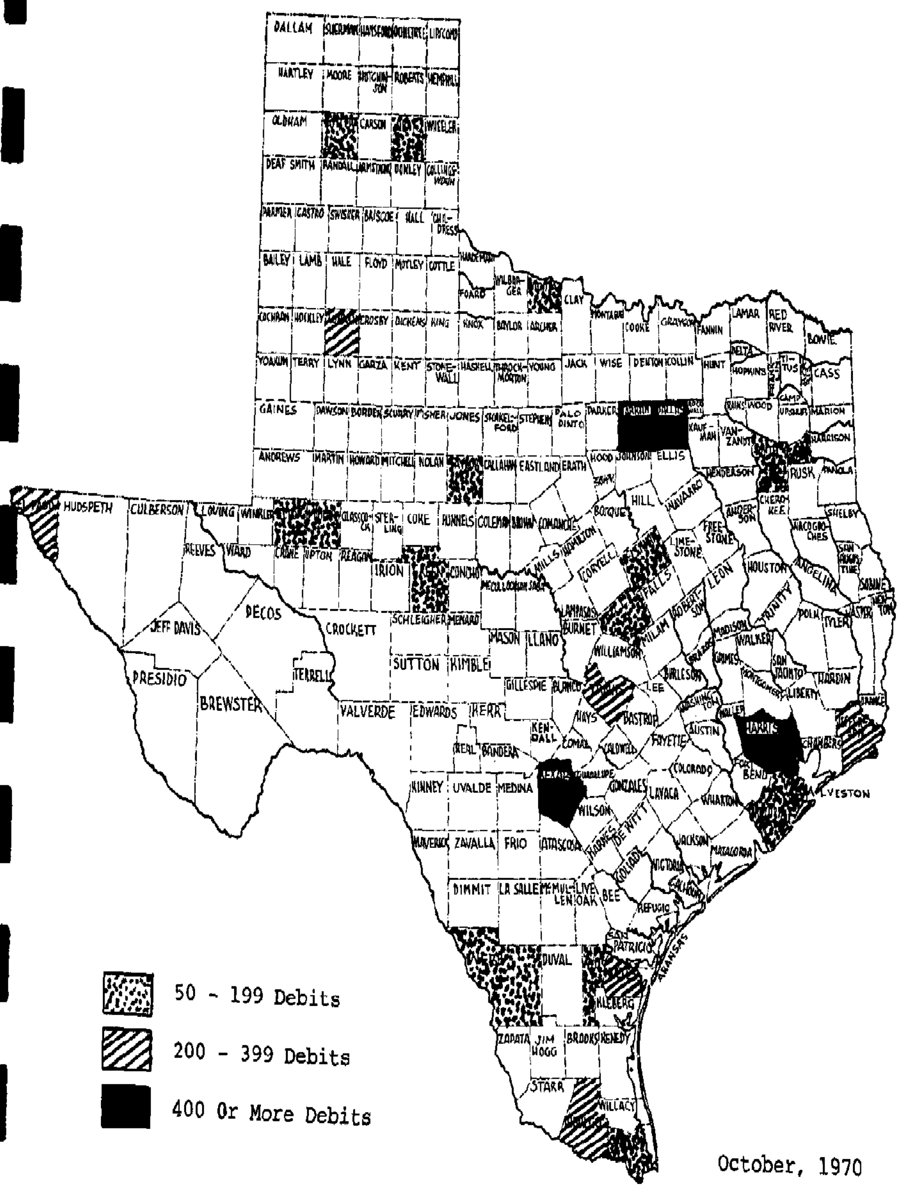
Local Health Services

One of the biggest public health problems in our State, as well as on the coast, is *the cost and delivery of health services.* There are not enough local health departments and programs, and the Texas State Department of Health is working toward the goal of complete coverage through the activation of a regional public health system.

Plate V indicates the location of the full-time county health departments in the coastal area (50% coverage).

PLATE IV

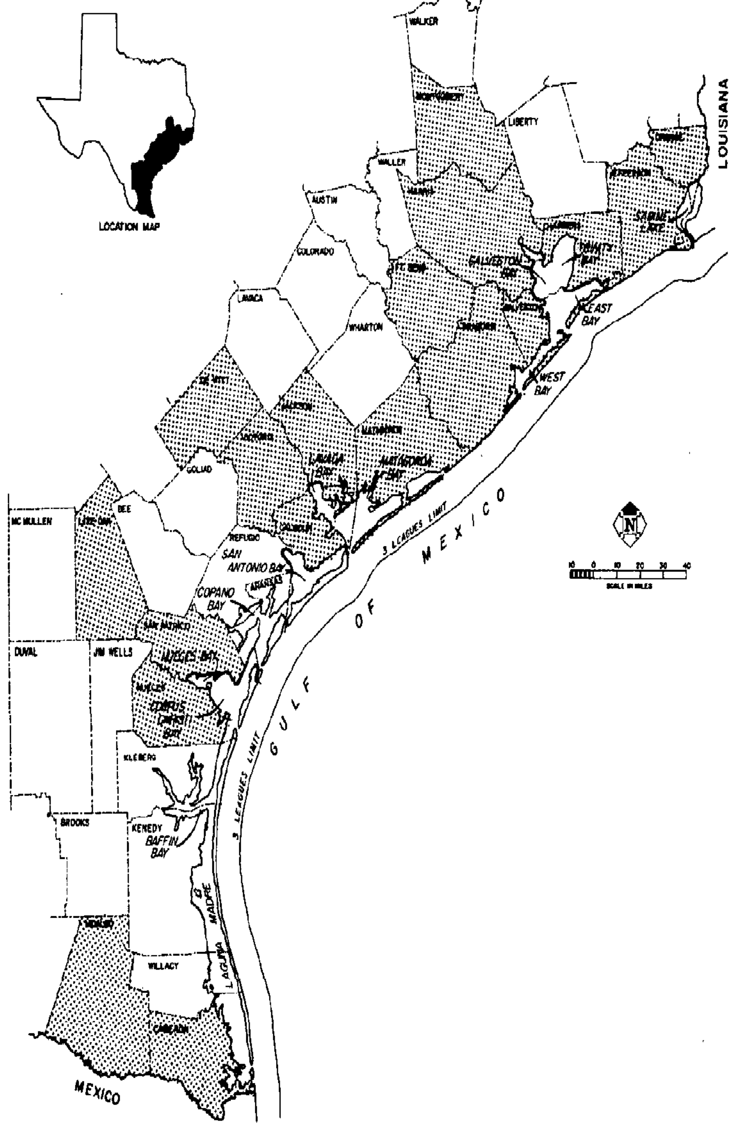
COUNTIES WITH THE GREATEST
NUMBER OF DEBIT EMPLOYERS



October, 1970

PLATE V

COUNTIES WITH FULL TIME
HEALTH DEPARTMENTS
(Shaded Area)



October, 1970

Communicable Diseases

It's one thing to be in the "Top Ten" in football, but to be a national leader in the disease field is a somewhat dubious honor. From a review and analysis of the statistics, it is evident that *Texas has more than its share of communicable diseases.* In a report prepared in October, 1970, by the Texas Office of Comprehensive Health Planning, the 1968 statistics on 12 selected communicable diseases (see Table III) are analyzed. These diseases were chosen because they are believed to be the most accurately reported and thus are better suited for comparison. *The incidence rates in Texas for nine out of the 12 were higher than the respective U. S. rates.*

The rates were also calculated for the Coastal study area (the five planning regions contiguous to the coast) and are compared with the Texas and U. S. figures (Table III). The results are shown graphically in Plate VI, and it can be seen that the rates in the coastal region for nine out of the 12 are higher than the U. S. average; seven out of 12 are higher than the U. S. and Texas averages.

Tuberculosis is one of the most prevalent diseases in the coastal area, and it is probably *the most common* among migrant farm workers (see section on Migrant Health Program below). The Coastal region has about 30% of the State's population, but approximately 40% of the new active cases in Texas each year are found there (highest incidence areas: Houston and the Texas-Mexico border). The case rates for that part of the state are in the range of 35 to 38, whereas, the rate for the whole state has been in the range of 26 to 30. Climate has no bearing on TB incidence; the significant factor is *concentration of people*. One-fifth of all the cases in Texas come out of the Houston area (Harris, Montgomery, Brazoria, Fort Bend, Galveston, Waller, Austin, and Walker Counties). The eradication program presently includes case finding, treatment, treatment of "high-risk susceptibles," following inactive cases for five years after completion of therapy, and prevention through the child-centered testing program.

Veneral disease is a constant problem; the incidence in Texas is higher this year than ever before. There has been a *498% increase* in infectious/early syphilis in the State since 1958. A portion of this increase is undoubtedly due to improved case finding. The following statistics should serve to further illustrate the problem.

REPORTED CASES

	State	Coastal Area	%
Total syphilis (all stages), 1969	6,170	2,907	47.1
Total syphilis, Jan. - Sept., 1970	4,871	1,930	39.6
Infectious/early syphilis, Jan. - Sept., 1970	3,602	1,307	36.3
Gonorrhea, 1969	38,405	14,817	38.6
Gonorrhea, Jan. - Sept., 1970	32,689	12,180	37.2

TABLE III

REPORTED COMMUNICABLE DISEASES
1968

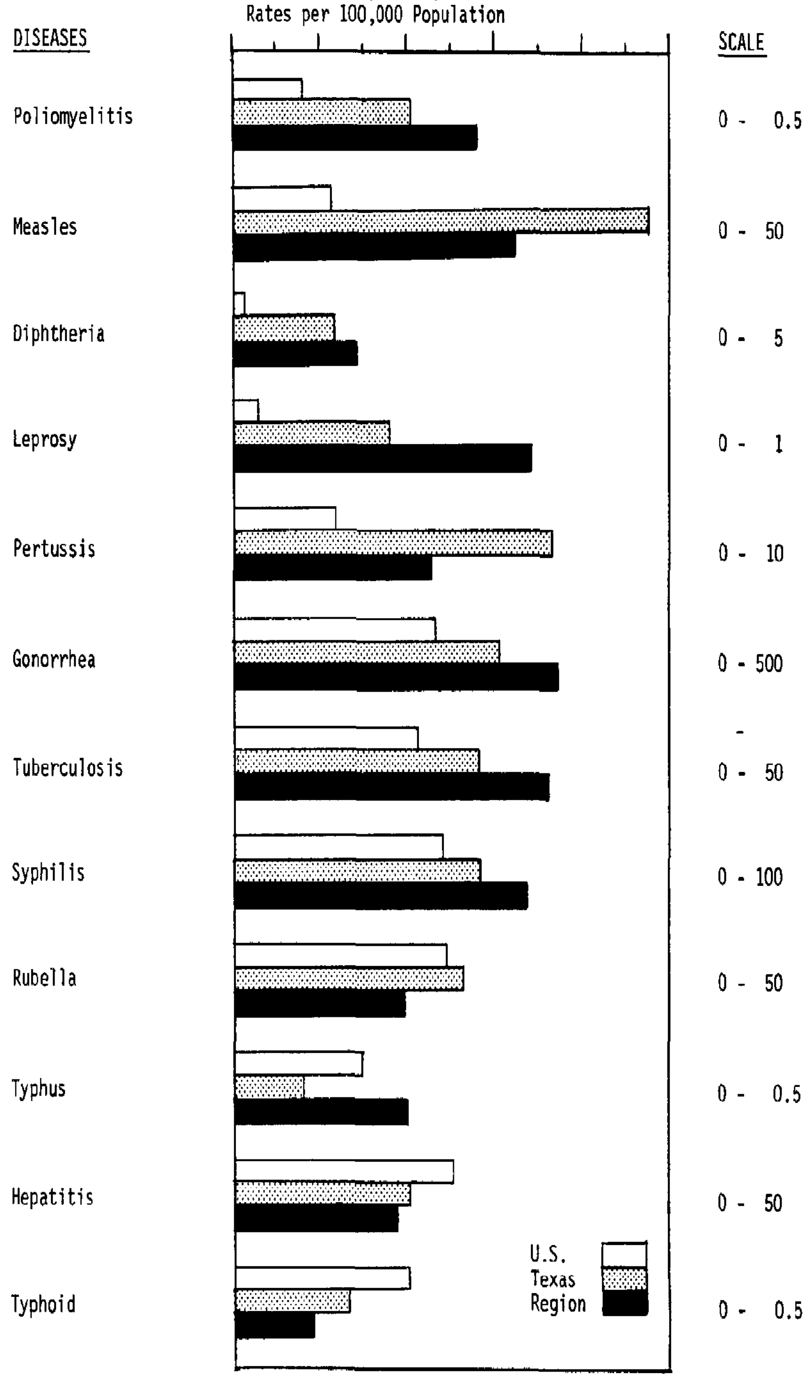
	United States		Texas		Coastal Region		Region's Percentage	
	Number	Rate*	Number	Rate*	Number	Rate*	Of U.S. Rate	Of Texas Rate
Poliomyelitis	53	0.03	22	0.20	10	0.28	933.3	140.0
Measles	22,231	11.12	5,204	47.40	1,139	32.20	289.6	67.9
Diphtheria	260	0.13	131	1.19	50	1.41	1,084.6	118.5
Leprosy	123	0.06	40	0.36	24	0.68	1,133.3	188.9
Pertussia	4,801	2.41	802	7.31	147	4.15	172.2	56.8
Gonorrhea	464,543	232.43	33,667	306.70	13,158	371.60	159.9	121.2
Tuberculosis	42,758	21.39	3,108	28.31	1,289	36.40	170.2	128.6
Syphilis	96,271	48.17	6,208	56.55	2,371	67.00	139.1	118.5
Rubella	49,371	24.70	2,923	26.63	692	19.50	78.9	73.2
Typhus	298	0.15	9	0.08	7	0.20	133.3	250.0
Hepatitis	50,722	25.38	2,300	20.95	670	18.90	74.5	90.2
Typhoid	395	0.20	14	0.13	3	0.09	45.0	69.2

* Rates per 100,000 population

PLATE VI

REPORTED COMMUNICABLE DISEASES - 1968

COMPARING RATES IN U.S., TEXAS, AND COASTAL REGION
Rates per 100,000 Population



It can be seen that the incidences for the first nine months of 1970 are very near the totals for the previous year. Only Dallas is on a competitive level in incidence. *(NOTE: Bear in mind that the reported figures from which these VD statistics are compiled only represent approximately 25% of the actual cases).*

Leprosy in Texas is high, and most of the cases come from the coastal zone. There has been a vigorous case-finding effort since 1961, and at present there are *500+ cases* under surveillance. These cases have always been there, but not until recently have they been found and treated.

The *dysenteries*, including *amoebiasis*, are seen mostly among the lower socio-economic groups (not an ethnic problem), usually as a result of *poor personal hygiene and sanitation.* Although *hepatitis* is commonly listed among water-borne diseases, it is spread more by not washing hands. An adequately financed environmental health program can do much in these cases.

Diphtheria, poliomyelitis, measles, pertussis, and *rubella* are "immunizable" diseases; we shouldn't have them. They crop up whenever immunization levels are allowed to become low.

Mention should be made of the *zoonoses* - diseases transmitted from animals to man - such as *brucelosis, anthrax, botulism,* and *rabies.* Of these, rabies is a constant menace; present especially in wild animals, and prevalent at this time in the Rio Grande Valley, West Texas, and Central Texas (the high reservoir in Central Texas exists because of the large number of *bat caves).*

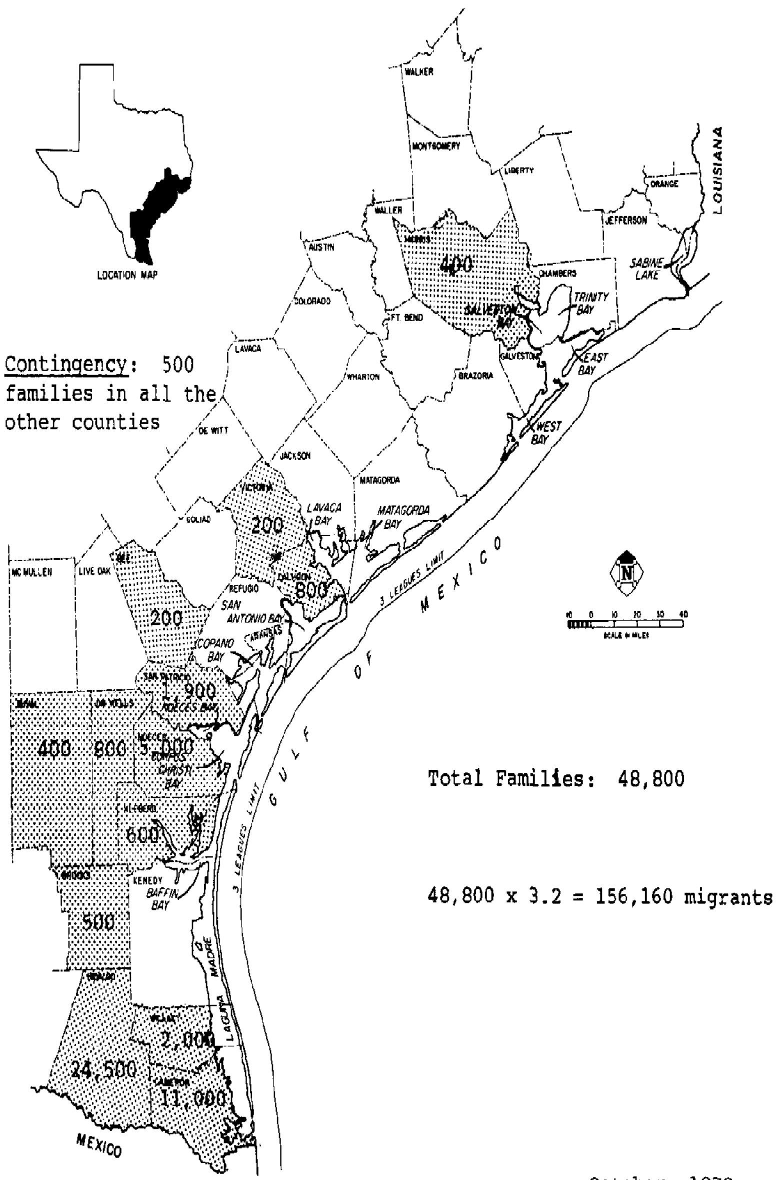
Migrant Health Program

The primary purpose of the Migrant Health Program of the Texas State Department of Health, which was coordinated through the Division of Sanitary Engineering until 1963, is *to improve health care and services for migrant agricultural workers.* The greatest concentration of activity associated with this program is in the Lower Rio Grande Valley and the coastal zone. Plate VII shows the location of the estimated 156,000 migrants in the coastal zone.

The language barrier and the general unavailability of education and educational programs among the migrant workers are significant parts of the cause of the major problems that affect the health of these people. These problems, for the most part, are *environmental in nature:* Crowded and substandard housing, inadequate water and sewerage facilities, no insect and rodent control, little or no garbage collection. The health problem is compounded by the fact that usually the migrant *will not* seek a doctor until he is seriously ill. The Texas Education Agency, as well as the State Health Department, takes an active part in the Migrant Health Program toward overcoming this problem. Mechanization has also compounded the problem by putting many migrants out of work, i.e.,

PLATE VII

LOCATION AND ESTIMATED NUMBER
OF MIGRANT FAMILIES



Contingency: 500 families in all the other counties

Total Families: 48,800

48,800 x 3.2 = 156,160 migrants

October, 1970

migrants have less money to spend for health care, and more of a financial burden is placed on the health care system.

The "serious" disease most common among these people, and certainly most prevalent among them in the coastal zone, is *tuberculosis*. The greatest number of patients (with all diseases) is in the age range of 15 to 44.

One interesting aspect of the migrant situation that may have an effect on the Migrant Health Program is the fact that the *minimum wage* law has caused many large land owners in the Rio Grande Valley to dry up their fields and move into farming operations across the border into Mexico. The workers, who actually have an opportunity to make more money working on a unit basis than by the hour, have also migrated south.

Maternal and Child Health, Nutrition, and Family Planning

The problems in these areas can be credited to the extreme poverty of the high minority group population and the rapid growth and industrialization of the coastal region. *Improper and insufficient pre- and post-natal care* are given, and there are more cases needing treatment than there are facilities for treatment.

This situation is also characterized by a *poor nutritional state*. Many babies are born potentially retarded because of poor nutrition.

There is a high and increasing number of *teenage pregnancies* in the coastal region. The adolescence of the mothers is also a major contributing factor to babies being born potentially retarded (of abnormally small size). Morbidity increases in both mother and child as a result of the mother having too many children. It is estimated that there is three times more morbidity in having too many children that in taking "the pill."

IV. HURRICANE-CREATED HAZARDS

When an area is devastated by a hurricane, as has been the case many times before in the coastal area, special health and sanitation problems, mostly of an environmental nature, are presented.

Water Supply

Power outages, which usually occur, render water system pumping equipment inoperable. Pressure on the distribution system soon decreases, thus increasing the chances of contaminants entering the system. In addition, water cannot be taken from the source of supply for treatment and delivery. To overcome this situation, an auxiliary power source (gasoline engine) is needed. The majority of the cities in the coastal area *do not* have auxiliary power facilities.

Water Pollution

Sewerage systems are often flooded, and septic tanks are underwater. When this situation occurs, there is no collection of wastewater and no effective treatment.

Solid Waste

A solid waste management and disposal problem of large magnitude is created; everything that has been destroyed is classified as solid waste. To help alleviate the situation, the Texas Air Control Board grants an *immediate variance* for open burning of the refuse and litter.

Vector Control

Dead cattle and other animals attract and breed *flies; rats* are displaced and come out to look for food. Heavy rain often accompanies a hurricane (Hurricane Celia in August, 1970, was relatively "dry," however.), and the *mosquito* population is increased; their presence is detected about the fifth day after the storm. High winds blow out windows and screens, and windows without screens are opened for ventilation because power outages have "knocked out" air conditioners, and the mosquitoes come in. A health problem results when a "disease reservior" (*encephalitis,* most commonly) develops.

Shellfish

Pollution and contamination of the coastal waters result when high tides and heavy rains flood the adjacent country-side. A large amount of debris and urban runoff are washed into the bays. The oyster harvesting areas must then be closed for two to six weeks until sampling and testing can acertain safe bacterial levels. This does not happen very often, however.

Food

Contamination of food results; directly from wind and water, indirectly from spoilage when power goes off. More surveillance is needed in salvage operations to insure proper procedures and salvage of only the "correct" food products.

Radiation

Radioactive sources are occasionally blown around and sometimes lost. Surveillance teams (Texas State Department of Health) are rushed to the area to determine the severity and extent of the problem and to confine it and prevent spreading.

V. *DISCUSSION*

A conservative prediction (and this may be a gross understatement) of *growth and development in the coastal region is that it will continue, and probably at an increasing rate.* This is indicated by the influx of industry into the area and corresponding impact on the economy of our State, access to and development of suitable recreation centers, and the concentration of population in that part of the State; especially the Houston area. *More people mean more problems,* and public health is no exception. Since the people are what make things happen and keep things going, there is the obvious need to keep them healthy. It follows, therefore, that the State Legislature and the environmental protection agencies, especially the Texas State Department of Health, must direct a significant part of their attention and effort to the coastal region.

Texas has more undeveloped *(unspoiled?)* coastline than any other state. There is still time for productive, thrifty, and orderly development to take place - in contrast with the East Coast, for example, that is presently trying to "salvage and regroup" in many locations - if planning for a healthy environment is effected in the relatively near future.

The present trend of proliferation of small water and sewerage installations must not go unchecked; *master water systems and regional sewerage systems* must be developed for good public health protection. It may be well to examine the attitude and philosophy regarding water use and needs, water wastage, pollution control, and pricing of this product. *Will each of us really need 200+ gallons of water per day by the year 2000? If so, where is it going to come from? Is the answer to water quality control the construction of more and larger wastewater treatment plants?*

A change in public attitude toward the water utilities profession and the value placed on the services rendered by these people is urgently necessary. The quality of public health protection in this field is *directly proportional* to the price paid for it, and right now, the amount being spent for salaries and facilities is very low. A *greens keeper* at a municipal golf course receives a higher salary than the man responsible for supplying safe water to the public.

There has been *very* little planning done for *solid waste management,* not to mention improper operation of existing disposal facilities. Because of increasing unavailability of land for disposal, alternate solutions must be sought to reduce the amount of refuse being generated and to dispose of the tonnage that is and will be confronting us.

Complete area coverage by *mosquito control districts* operating in conjunction with full-time, active local health departments will be a necessity to combat vector-borne and other communicable diseases that hang as a Sword of Damocles over this subtropical, receptive region.

In addition to water quality control measures and intensified sanitary surveillance of estuary and land areas - necessary to protect our marine resources - in the entire coastal zone, stricter regulation of the *seafood production and processing industry* will be needed.

The general public and public health officials are indeed concerned at the present time - maybe "in an uproar" is a better term to describe the situation - over the *diphtheria epidemic* in our state (San Antonio); *about 200 cases* with *two or three deaths*. Why is there not the same loud outcry over the *syphilis epidemic (over 3,000 cases with about 150 deaths in our state each year* - and bear in mind, again, that these reported figures represent only 25% of the actual cases)? *Is our public health surveillance effort properly directed?* It might be well for we the people to reexamine our attitudes and philosophies toward public health practices and standards.

VI. CONCLUSION

1. An intensified public health *education program* for environmental health and communicable diseases.

2. More emphasis on health care delivery, facilities, and environmental protection for the *transient segment* of our population, especially the tourist.

3. Development of *regional water and sewerage systems* and more rigid control of the use of septic tanks in the densely populated areas.

4. *Improved solid waste* management techniques and planning.

5. Complete coverage of the area by *mosquito control districts* and local health units.

6. More intense sanitary surveillance for protection of our *marine resources*, and *additional regulation* of the seafood production and processing industry.

7. Additional personnel are needed for such *consumer protection programs* as bedding (regulation of the sale of second-hand bedding material) and food and drug surveillance.

8. An environmental facilities/land use plan for the entire coastal area.

9. Intensified effort toward *tuberculosis* case-finding, treatment, and eradication.

10. A reinforced program for veneral disease case-finding and treatment, and increased state funding for facilities and personnel for treating the cases.

11. A continuous and concerted effort toward *immunization* of all persons, especially children, for the "immunizable" diseases.

12. A serious and intense *family planning* and *"zero population growth"* program with special attention and force directed toward young teenagers.

13. *Reexamination of attitudes, philosophies, and standards regarding public health practices, use of natural resources, and environmental control techniques.*

14. It could go without saying that adequate funding, along with an enlightened attitude, is needed to implement the items listed above.

INVENTORY OF WASTE SOURCES

IN THE COASTAL ZONE

Prepared by

Professor Joseph F. Malina

Center for Research in Water Resources

and

Environmental Health Engineering Laboratories

The University of Texas at Austin

October 1970

for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

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PREFACE

This report summarizes the available data which characterizes the quality of the environment of the Coastal Zone of Texas. The inventory of waste sources is based on existing data compiled by the various State agencies. The data were collected during the time period, August 15, 1970 through September 15, 1970 and therefore represent the accessible information on record at that time. The time limitation also made it almost impossible to include data which were on file but not available in a readily usable form. No attempt was made to actually collect samples in the field in order to supplement the available data.

The cooperation of the personnel of the various State agencies was essential to the completion of the inventory within the time frame work. The assistance of the personnel of the following agencies is acknowledged:

Texas Water Quality Board

Texas Water Development Board

Division of Planning Coordination, Office of the Governor

Texas Air Control Board

Texas State Department of Health

Texas Highway Department

The compilation and collection of the data would not have been possible without the assistance of Mr. Dennis J. Crowley. The assistance of Mr. Camilo Guaqueta in reducing the data for use in this report is also acknowledged. Mr. Crowley and Mr. Guaqueta are Research Engineers in the Environmental Health Engineering Laboratories at The University of Texas at Austin. The preparation of the final manuscript was completed by the secretarial staff of the Environmental Health Engineering Laboratories at The University of Texas at Austin. Typing of the final copy for printing was done by Marilyn Purdy.

I. INTRODUCTION

The use of the resources along the Texas Gulf Coast has resulted in changes in the air, water, and land environments. The extent and the type of environmental change depends on the type of activity. The effect of industrial utilization of natural resources is considerably different than the environmental changes caused by agricultural development. Large scale industrialization results in urbanization and the associated high population densities. The effects of this urbanization on the environment is different than the effects caused by small rural communities. *Man's activities have left their mark on the environment and this report is an attempt to evaluate the extent of environmental change caused by man's use and development of the natural resources in the Coastal Zone of Texas.*

Objectives

The primary objective of this report is to develop an inventory of the existing sources of waste materials discharged into the water and air and deposited onto the land in the Coastal Zone of Texas. These sources of potential pollution include *municipal and industrial wastewaters, solid wastes, and gases and particulate material discharged into the atmosphere.* A second objective is the evaluation of the inventory of waste discharges in an attempt to identify those areas where sufficient information is not available and to propose methods of obtaining the data. The final objective is recommendations of programs of action to improve the quality of the environment in the immediate future as well as for long-range planning purposes.

Scope

The inventory of waste sources and emissions includes the more obvious environmental insults caused by improper disposal of municipal and industrial solid wastes or inadequate treatment of municipal and industrial wastewaters as well as some of the more subtle potential pollution sources such as pesticides in the bay and estuaries as well as the emissions from motor vehicles. This inventory is developed *based on existing information from the records* of the Texas Water Quality Board, Texas Water Development Board, Texas Air Control Board, Texas State Department of Health, Texas Department of Public Safety, the U.S. Geological Survey and the Texas Parks and Wildlife Commission, and other published documents. In cases where similar data were available from more than one source, all attempts were made to reconcile any discrepancies which may have existed among the data.

Coastal Zone

The inventory of waste sources was limited to those counties which are considered to be in the Coastal Zone of Texas. The Coastal Zone includes 36 counties and covers an area ranging from Orange and Jefferson Counties along the Sabine River down to Hidalgo and Cameron Counties along the Rio Grande River.

The study area includes *33,451 square miles of land* plus approximately *6,300 square miles of submerged land* in the bays. The dry land area represents approximately 12 percent of the area of the State. The bays and estuaries along the Texas Gulf Coast provide the spawning and nursery areas on which much of the commercial fisheries industry is dependent. The population for the counties included in this study is *3,538,763 people* according to the initial 1970 Census data. This population represents 32.2 percent of the total estimated population of Texas for 1970.

The Coastal Zone provides a contrast. The highly industrialized and populated area between Beaumont and Houston is considerably different than the relatively undeveloped area between Freeport and Brownsville, with the exception of the Corpus Christi area. The extent and type of industrial activity as well as concentration of population can be related to the sources of waste as well as to the efforts and funds expended in attempts to satisfactorily treat and dispose of waste materials. The extent of agricultural development can be related in part to the quantity of herbicides and pesticides that may be found in the bay and estuary system.

The inventory of waste sources includes:

municipal and industrial wastewaters
salt water discharges
municipal refuse
refuse disposal practices
industrial emissions to the atmosphere
emissions from motor vehicles
animal wastes and pollution potential
pesticides in bays and estuaries

Other actual or potential waste sources which were not included in the inventory because of the limited time available for the completion of the study include releases of wastes associated with the transportation of materials by *pipelines and ships; dredging* for channel improvement or for utilization of mineral resources; and *litter and debris* from recreational activities associated with the beaches and waters of the Coastal Zone. Also, thermal discharges were not enumerated here since they are dwelt upon at length in a separate report on energy and power in the Coastal Zone.

II. INVENTORY OF WASTE SOURCES

The waste products of man's municipal and industrial activity which are discharged into surface water, onto the land, into the atmosphere or below ground have been identified where data was available. These data are summarized in this section of the report. This information includes:

(a) quantity and quality characteristics of municipal and industrial wastewater discharged into surface waters;

(b) quantity of industrial wastewaters disposed of by injection wells;

(c) salt water discharges and methods of salt water disposal;

(d) production of municipal solid wastes and current refuse disposal practices;

(e) particulate and gaseous emissions into the atmosphere from industrial sources;

(f) the number of registered motor vehicles and characteristics of automobile exhausts;

(g) animal production, feed lots and potential solid waste and water pollution problems;

(h) pesticides in the water and sediment of bays and estuaries;

(i) radioactive wastes

Wastewater Discharges

The wastewater generated from the use of water for municipal and industrial purposes contains *suspended and dissolved, organic and inorganic materials* which can effect the quality of the receiving waters. Many of the components of wastewaters are reactive and undergo *biological decomposition* or enter into chemical reactions in the aquatic system. The *setteable solids* will accumulate on the bottom of streams and the organic material in the sediments will decompose. The concentration of these materials will decrease with time and these substances are nonconservative. Some of these materials, however, are *nonreactive and persist in the aquatic* environment for long periods of time. These conservative or refractory materials are generally not affected by conventional water and wastewater treatment processes and *tend to accumulate in the water, in sediments, or in aquatic organisms.*

Other components of wastewaters are classified as *nutrients* since relatively low concentrations of these chemical elements are required by algae and have been associated with the occurrence of undesirable algal blooms in streams, lakes, estuaries and bays. These nutrients are also associated with accelerating *eutrophication* which is a natural process of aging occurring in bodies of water.

Some inorganic ions and some organic compounds are *toxic* to fish, other aquatic animals and algae. At high concentrations these materials can exert acute toxic effects resulting in dramatic results such as fish kills. Chronic exposure to sublethal concentrations of these materials can have more *subtle effects on the biota*. Algae tend to accumulate and concentrate some toxic substances. Predator fish feeding on these algae could ingest lethal doses of toxicants. Inorganic ions which have toxic effects include syanides, mercury, copper, cadmium, chromium, zinc, and nickel to name a few. Some other compounds and petrochemicals usually involved in reports of acute toxicity are acids, caustics, ammonia, chlorine, phenolic compounds, organic solvents, synthetic organic compounds, oil field brines, pesticides and detergents to list only a few.

Most pollutants are characterized by the *oxygen demand* on the receiving streams exerted by the wastewater discharges. Dissolved oxygen is required by fish and aquatic organisms. When there is no free dissolved oxygen in the water anaerobic conditions result in fish kills and are characterized by odors. The lack of dissolved oxygen generally upsets the "biodynamic" equilibrium which relates the interdependence of various aquatic species on each other and the effects of oxygen, nutrients and organic material on the organisms. *Biodynamic equilibrium* is characterized by numerous species of bacteria, algae, protozoa, crustacea and fish. Each species is present in limited numbers. The equilibrium is upset when the aquatic environment is changed resulting in the elimination of one type of organism and the predominance of another. Depletion of the dissolved oxygen resources changes the environment from aerobic to anaerobic and the biodynamic equilibrium which was established is upset.

The *dissolved oxygen balance in the receiving stream is important;* therefore, wastewaters must be classified in terms of their effects on the oxygen resources of the stream. Wastes are classified in terms of a Biochemical Oxygen Demand *(BOD)*, a Chemical Oxygen Demand *(COD)* or a Total Oxygen Demand *(TOD)*. Wastewaters are also characterized in terms of the Total Organic Carbon *(TOC)* content, which can be related to one of the oxygen demand parameters.

The Biochemical Oxygen Demand *(BOD)* is the quantity of oxygen utilized in the *microbial oxidation of biodegradable organic material* in the wastewater in a specific time (usually 5 days) and at a specific temperature (usually 68°F). The BOD usually indicates the oxygen required for the biological oxidation of biodegradable carbonaceous substances and in some cases for the degradation of nitrogenous materials.

The Chemical Oxygen Demand (COD) represents an estimate of the organic and inorganic materials which can be *oxidized by a chemical oxidizing agent*. The Total Oxygen Demand (TOD) is a relatively new parameter for which equipment has recently been developed and provides an estimate of the oxygen required to *satisfy all demands on the oxygen resources* in the stream. Equipment is also available for estimating the amount of organic and inorganic carbon in the wastewater. The TOC can be related to the BOD and/or COD.

The analytical procedures available for evaluating the parameters used to characterize the oxygen demand or carbon content of wastewaters have some limitations. A detailed discussion of all the procedures is beyond the scope of this report. *However, it is important to note that extreme caution is advisable in evaluating data relating to these parameters.*

The particulate and dissolved substances in wastewaters also effect the quality of the receiving stream. Deposition of organic and inorganic suspended material on the bottom of streams can cause sludge banks to form. The accumulation of dissolved solids in the water can limit the use of the water for some purposes. The solids in wastewaters are categorized below:

(a) setteable solids are the suspended matter in a waste which will settle by gravity under quiescent conditions in one hour.

(b) suspended solids are those materials which float on the surface or are in suspension in water and which are removed by laboratory filtering

(c) total solids are defined as the residue remaining after the water is evaporated from the sample and the residue dried to a constant weight

(d) dissolved solids are therefore the difference between the total solids and the suspended solids

(e) volatile solids are that fraction of the total suspended or dissolved solids which are lost upon ignition of the dried residue.

The characteristics of typical municipal wastewater are summarized in Table 1. The introduction of industrial wastewater into the collection system may markedly alter the composition of municipal wastewater. The amount of water used and the quantity of infiltration into the collection system also effects the characteristics of municipal wastewater.

The quantity of wastewater generated per person in Texas varies from less than 70 to 100 gallons per capita per day. The per capita wastewater flow increases with the population of the city. This increase may be attributed to the fact that larger quantities of water

TABLE 1

Characteristics of Typical Municipal Wastewater*

Characteristic	Maximum	Average	Minimum
pH Units	7.5	7.2	6.8
BOD (mg/l)**	276	147	75
COD (mg/l)	436	288	159
Settleable Solids (mg/l)	6.1	3.3	1.8
Total Solids (mg/l)	640	453	322
Suspended Solids (mg/l)	258	145	83

* Hunter, J. V., and H. Heukelekian
"The Composition of Domestic Sewage Fractions,"
Journal Water Pollution Control Federation, 37, 1142 (1965)

**mg/l = milligrams per liter = parts per million are used for public purposes in the communities. Therefore, when the wastewater from public facilities is assessed on a per capita basis, this value will increase. *The average municipal wastewater flow in Texas is 88.9 gallons per capita per day*. The average contribution of 5-day BOD and suspended solids for people in Texas respectively are *0.16 pounds and 0.21 pounds per capita per day*. These values are considerably lower than those reported for the national average values for these parameters which are 135 gallons of wastewater, 0.20 pounds of 5-day BOD, and 0.23 pounds of suspended solids per capita per day, respectively.

The characteristics of industrial wastewaters are as varied as the type of industry producing the wastes. The composition of wastewaters from different industries are presented for illustrative purposes in Tables 2 and 3.

Most municipal and industrial wastewaters have been treated to some extent to improve the effluent quality before discharge into the surface waters. The number of treatment plants in each county in the Coastal Zone are presented in Figure 1 and Table 4. The information was obtained from the data maintained in the form of an inventory of waste treatment facilities at the Texas Water Quality Board for all wastewater discharges for which permits have been granted. These permits are required under the State Water Pollution Control Act passed by the 57th Legislature of the State of Texas in 1961.

Current technology of wastewater treatment and renovation is such that the removal of almost all non-desirable constituents of wastewater is possible for some price. Treatment or renovation of wastewater is usually classified as *primary, secondard or tertiary*. *Primary treatment* includes numerous processes required for the removal and disposal of a portion of the suspended solids in the wastewater. *Secondary treatment* involves the removal of a portion of the dissolved organic material in the wastewater by means of microbiological oxidation. These processes are aerobic and vary in the way in which the bacteria are utilized. Waste stabilization ponds contain algae which provide the oxygen for use by bacteria in oxidizing the organic material. The effluent BOD is a function of the detention time and temperature. The effluent suspended solids concentration is between 50 and 100 mg/L. Trickling filters are treatment units in which bacteria which oxidize the organic matter grow in the form of slime attached to the surface of a rock or suitable support. These bacteria oxidize the organic matter with which they come in contact as the wastewater passes over the slime covered medium.

Activated sludge is the general name applied to a number of similar processes which involve the introduction of oxygen into a system containing a mixture of suspended bacterial growths (activated sludge) and the dissolved organic material in the wastewater.

TABLE 2

Industrial Wastewater Characteristics

Industry	Flow (gal)	BOD (lb)	SS (lb)	Other	
Brewery					
per barrel	370	1.9	1.03		
Cannery					
per case	75	0.7	0.8	Total Dissolved Solids	
Dairy					
per 100 lb					
Creamery butter	410-1350	0.34-1.68	---		
Cheese	1290-2310	0.45-3.0	---		
Condensed and evaporated milk	310- 420	0.37-0.62	---		
Ice Cream	620-1200	0	---		
Milk	200- 500	0.05-0.26	---		
Meat Packing per 100 live wt. killed					
old technology	2112	20.2	---		
typical technology	1294	14.4	---		
advanced technology	1116	11.3	---		
Poultry Processing per 1000 birds					
old technology	4000	31.7	---		
typical technology	10400	26.2	---		
new technology	7300	26.0	---		
Petrochemical Plants					
Petroleum Refining				Phenol	Sulfide
per barrel					
old technology	250	0.4	---	0.03	0.01
typical technology	100	0.1	---	0.01	0.003
newer technology	50	0.05	---	0.005	0.003

TABLE 2
(cont'd.)

Industry	Flow (gal)	BOD (lb)	SS (lb)	Other
Pulp & Paper				
per ton				
Bleached Kraft				
old technology	110,000	200	200	
prevalent technology	45,000	120	170	
new technology	25,000	90	90	
Bleached Sulfite				
old technology	95,000	500	120	
prevalent technology	55,000	330	100	
new technology	30,000	100	50	
Steel Mill				
per ingot ton				
old technology	9,860	---	103	Phenols, cyanides
prevalent technology	10,000	---	125	Fluorides, ammonia
new technology	13,750	---	184	oil, acids, emulsions, soluble metals
Tannery				
per 100 lb	660	6.2	13.0	
Textile				
per pound of cloth				
Wool	63	0.30	---	
Cotton	38	0.16	0.07	
Synthetic				
Rayon	3- 7	0.02-0.04	0.02-0.09	
Acetate	7-11	0.04-0.05	0.02-0.06	
Nylon	12-18	0.04-0.06	0.02-0.04	
Acrylic	21-29	0.10-0.15	0.03-0.15	
Polyester	8-16	0.12-0.25	0.03-0.16	

<u>The Cost of Clean Water</u>, Volume III, Industrial Waste Profiles, Federal Water Pollution Control Administration, U.S. Dept. of Interior, Washington, D. C. (1968).

No. 1 Blast Furnaces and Steel Mills
No. 3 Pulp and Paper
No. 4 Textile Products
No. 5 Petroleum Refineries
No. 6 Canneries
No. 7 Leather Tanning and Finishing
No. 8 Meat Products
No. 9 Dairies

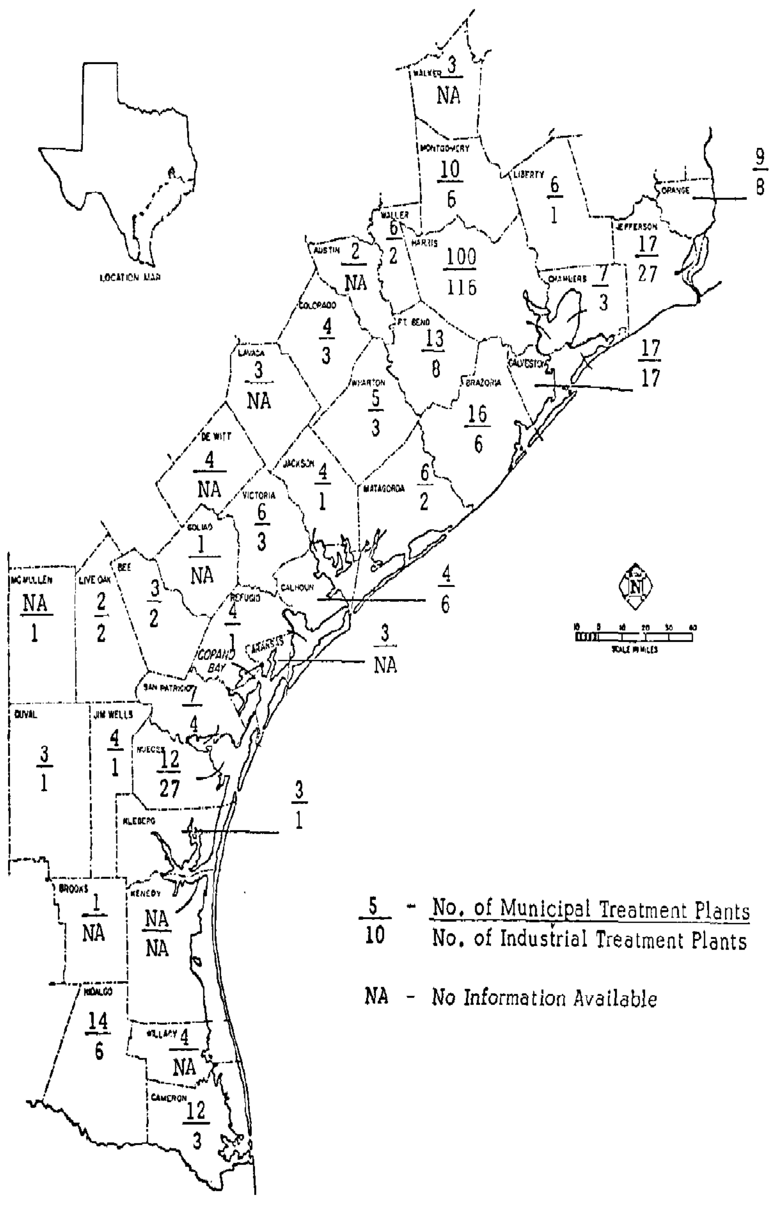
TABLE 3

Petro-Chemical Wastewater Characteristics

Chemical Product	Flow (gal/ton)	BOD (mg/l)	COD (mg/l)	Other Characteristics
Primary Petrochemicals:				
Ethylene	50-1,500	100-1,000	500-3,000	phenol, pH, oil
Propylene	100-2,000	100-1,000	500-3,000	phenol, pH
Primary Intermediates:				
Toluene	300-3,000	300-2,500	1,000-5,000	
Xylene	200-3,000	500-4,000	1,000-8,000	
Ammonia	300-3,000	25- 100	50- 250	oil, nitrogen, pH
Methanol	300-3,000	300-1,000	500-2,000	oil
Ethanol	300-4,000	300-3,000	1,000-4,000	oil, solids
Butanol	200-2,000	500-4,000	1,000-8,000	heavy metals
Ethyl Benzene	300-3,000	500-3,000	1,000-7,000	heavy metals
Chlorinated Hydrocarbons	50-1,000	50- 150	100- 500	pH, oil, solids
Secondary Intermediates:				
Phenol, Cumene	500-2,500	1,200-10,000	2,000-15,000	phenol, solids
Acetone	500-1,500	1,000-5,000	2,000-10,000	
Glycerin, Glycols	1,000-5,000	500-3,500	1,000-7,000	
Urea	100-2,000	50- 300	100- 500	
Acetic Anhydride	1,000-8,000	300-5,000	500-8,000	pH
Terephthalic Acid	1,000-3,000	1,000-3,000	2,000-4,000	heavy metals
Acrylates	1,000-3,000	500-5,000	2,000-15,000	solids, color, cyanide
Acrylonitrile	1,000-10,000	200- 700	500-1,500	color, cyanide, pH
Butadiene	100-2,000	25- 200	100- 400	oil, solids
Styrene	1,000-10,000	300-3,000	1,000-6,000	
Vinyl Chloride	10- 200	200-2,000	500-5,000	

TABLE 3
(cont'd.)

Chemical Product	Flow (gal/ton)	BOD (mg/l)	COD (mg/l)	Other Characteristics
Primary Polymers:				
Polyethylene	400-1,600		200-4,000	solids
Polypropylene	400-1,600		200-4,000	deashing solvents
Polystyrene	500-1,000		1,000-3,000	solids
Polyvinyl Chloride	1,500-3,000	50- 500	1,000-2,000	
Cellulose Acetate	10- 200	500-2,000	1,000-5,000	
Butyl Rubber	2,000-6,000	800-2,000	2,500-5,000	
Dyes and Pigments:	50,000-250,000	200- 400	500-2,000	heavy metals, color, solids, pH
Miscellaneous Organics:				
Isocyanate	5,000-10,000	1,000-2,500	4,000-8,000	nitrogen
Phenyl Glycine	5,000-10,000	1,000-2,500	4,000-8,000	phenol
Parathion	3,000-8,000	1,500-3,500	3,000-6,000	solids, pH
Tributyl Phosphate	1,000-4,000	500-2,000	1,000-3,000	phosphorus



WASTEWATER TREATMENT PLANTS

FIGURE 1

TABLE 4

WASTEWATER TREATMENT PLANTS

County	# Municipal Treatment Plants	Industrial Treatment Plants: # Based On Computer Print Out (1)	Industrial Treatment Plants: Total # Print Out & TWDB Info. (2)
Aransas	3	NA	NA
Austin	2	NA	NA
Bee	3	2	2
Brazoria	16	3	6
Brooks	1	NA	NA
Calhoun	4	2	6
Cameron	12	2	3
Chambers	7	3	3
Colorado	4	2	3
DeWitt	4	NA	NA
Duval	3	1	1
Fort Bend	13	5	8
Galveston	17	14	17
Goliad	1	NA	NA
Harris	100	88	116
Hidalgo	14	5	6
Jackson	4	0	1
Jefferson	17	18	27
Jim Wells	4	1	1
Kenedy	NA	NA	NA
Kleberg	3	1	1
Lavaca	3	NA	NA
Liberty	6	1	1
Live Oak	2	2	2
Matagorda	6	2	2
McMullen	NA	1	1
Montgomery	10	6	6
Nueces	12	19	27
Orange	9	8	8
Refugio	4	1	1
San Patricio	7	3	4
Victoria	6	1	3
Walker	3	NA	NA
Waller	6	2	2
Wharton	5	1	3
Willacy	4	NA	NA

* NA - No Information Available

The effluent of trickling filter and activated sludge plants contains between 15 and 25 mg/L of 5-day BOD and generally less than 20 mg/L of suspended solids.

The destruction of disease causing bacteria remaining after primary and/or secondary treatment is generally accomplished by adding *chlorine* to the plant effluent.

Tertiary treatment of water renovation systems include processes which will remove those substances which persist after primary and biological treatment. The persistent materials include:

(a) *suspended solids* which are removed by sand filtration or microstraining,

(b) *dissolved organic materials* which are removed by adsorption on activated carbon,

(c) *inorganic substances* measured as total dissolved solids (TDS) which may be removed by ion exchange, and

(d) *nutrients such as phosphorus* which may be removed by chemical precipitation and nitrogen which may be eliminated either biologically or by air stripping.

The solids removed or generated during the treatment of wastewaters also require treatment and disposal. The alternate systems for wastewater and sludge treatment and disposal include a myriad combination of various unit processes and, therefore, will not be attempted at this time. However, *improper handling and disposal of sludges can result in a source of water or air pollution.*

The wastewater discharge permit information maintained by the Texas Water Quality Board includes quantitative and qualitative data as well as the location of the treatment plant. This information is provided by the applicant for a permit. In addition to the permit data and return flow data which include actual wastewater flow and characteristics, data are also maintained for some of the permitted discharges. The quality information is based on grab samples of waste which do not represent the hourly and daily fluctuations. For the purpose of this inventory, the quantity of wastewater was expressed as a rate of flow in million gallons per day (MGD) and the quality of the wastewater was expressed in terms of those substances which exerted an oxygen demand expressed as a Biochemical Oxygen Demand (BOD) or the Chemical Oxygen Demand (COD) and as Suspended Solids (SS). Phosphate information is also included for municipal effluents where information is available. These quality parameters were selected because *this information is readily available for most discharges.* The data are summarized for each county in the Coastal Zone in Tables 5 and 6 and the flow data for the municipal and industrial wastewaters is presented in Figure 2. The Texas Water Development Board also provided some of the information regarding the total flow of wastewaters in the various counties. The wastewater flow information is based on the return flow data provided in the form of a computer printout.

TABLE 5

Municipal Wastewater Discharges*

County	Flow (MGD)	Quality: BOD Pounds/day	Quality: Suspended Solids Pounds/day	Quality: Phosphates Pounds/day
Aransas	1.39	564	867	71
Austin	0.53	347	245	83
Bee	1.30	314	240	366
Brazoria	9.89	2902	2970	977
Brooks	0.25	250	94	67
Calhoun	2.26	707	693	294
Cameron	15.18	8705	8243	1,703
Chambers	0.24	86	197	83
Colorado	1.52	1374	1368	134
DeWitt	2.81	432	455	216
Duval	0.50	200	218	15
Fort Bend	3.72	1293	1933	690
Galveston	14.95	16283	11257	1,788
Goliad	0.30	5	105	30
Harris	197.44	75443	128721	26,560
Hidalgo	18.25	8768	14752	2,504
Jackson	0.67	130	166	------
Jefferson	65.90	23258	12575	9,274
Jim Wells	2.60	990	814	1,002
Kenedy	------	-----	------	------
Kleberg	2.10	685	633	214
Lavaca	0.96	2838	1324	672
Liberty	0.96	267	329	35
Live Oak	0.55	102	274	59
Matagorda	2.72	1215	440	508
McMullen	------	-----	------	NA
Montgomery	2.05	774	878	371
Nueces	28.50	11825	5980	5,815
Orange	7.33	4345	1406	813
Refugio	0.86	476	664	199
San Patricio	3.34	1753	2373	915
Victoria	3.85	951	3078	2,461
Walker	2.35	510	589	650
Waller	0.32	170	150	47
Wharton	1.82	751	649	663
Willacy	1.03	76	54	61

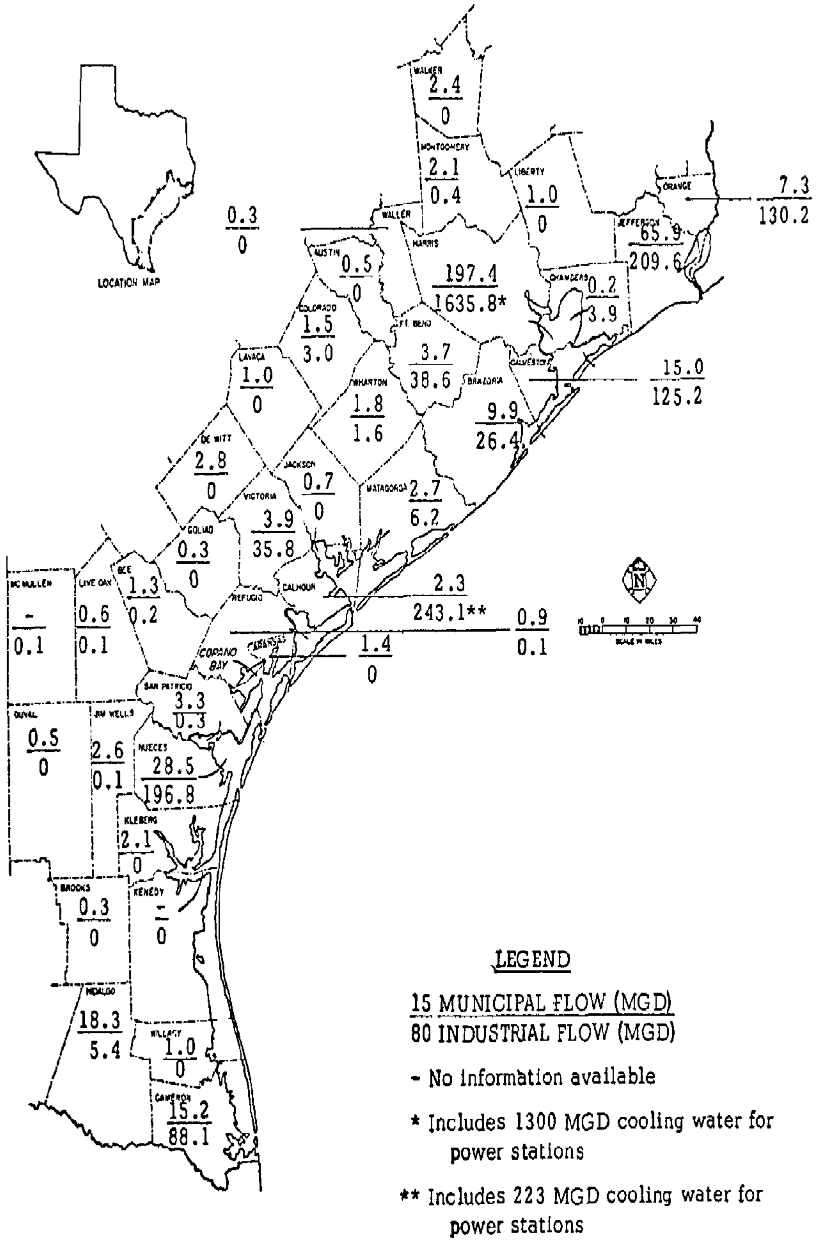
*Texas Water Quality Board (1970)
Texas Water Development Board (1970)

TABLE 6

Industrial Wastewater Discharges*

County	Flow (MGD)	BOD Pounds/day	Quality COD Pounds/day	Suspended Solids Pounds/day
Aransas	-------	------	-------	------
Austin	-------	------	-------	------
Bee	0.2	350	1401	856
Brazoria	26.35	2327	80147	1112
Brooks	-------	------	--------	------
Calhoun	20.11	2152	85644	15823
Cameron	88.11	2636	2114	20678
Chambers	3.93	847	30765	462
Colorado	2.98	20	67	22
DeWitt	-------	------	-------	------
Duval	-------	------	-------	------
Fort Bend	38.60	7750	12593	30878
Galveston	125.19	112767	950862	300620
Goliad	-------	------	-------	------
Harris	335.76	554260	1422807	555831
Hidalgo	5.36	221	1660	2703
Jackson	------	------	-------	------
Jefferson	209.55	183174	643791	130801
Jim Wells	0.09	66	162	55
Kenedy	-------	------	-------	------
Kleberg	-------	------	-------	------
Lavaca	-------	------	-------	------
Liberty	-------	------	-------	------
Live Oak	0.12	2	-------	------
Matagorda	6.24	9846	11885	2812
McMullen	0.07	1	240	60
Montgomery	0.41	737	7982	271
Nueces	196.83	65106	934978	76935
Orange	130.21	151395	341480	91919
Refugio	0.04	1	5	4
San Patricio	0.3	24	495	35
Victoria	35.78	6755	10088	13010
Walker	-------	------	-------	------
Waller	-------	------	-------	------
Wharton	1.59	34	135	336
Willacy	-------	------	-------	------

*Texas Water Quality Board (1970)
Texas Water Development Board (1970)



MUNICIPAL AND INDUSTRIAL WASTEWATER FLOWS (1970)

FIGURE 2

Much of the information relating to the wastewater quality for both the municipal and industrial discharges was not available in the return flow data. These data are collected by the staff of the Texas Water Quality Board and the lack of some data is a reflection of the under-staffing resulting from budget limitations.

The more recent data, namely that collected after February, 1970, would have to be obtained from the individual files and for each treatment plant which has a discharge permit. A system of self-reporting of the quality of the industrial wastewater influent has been initiated. However, as of this date, this system of reporting has been substantially less than 100 percent effective. As the self-reporting system develops and the difficulties eliminated, it would be possible to have monthly information regarding the effluent quality of each of the industrial discharges.

It should be pointed out at this time that the quality of the effluent from municipal and industrial wastewater treatment plants is affected to a large extent by the characteristics of the incoming wastewater, by the operation of the particular plant as well as the adequacy of the plant to handle the present day wastewater flows. The *infiltration of storm water or ground water* into the municipal wastewater collection systems in the Coastal Zone may also contribute to the total amount of flow which must be treated by municipal facilities. During periods of heavy rain it is possible that the infiltration of storm water into the collection system could result in overloading the treatment system thereby resulting in only partial treatment of the wastewater. The municipal wastewater flow presented in Table 5 and Figure 2 does *not* represent the contribution of infiltration into the collection systems in most cases. Therefore, these numbers are somewhat lower than the flow which would result during a period of high rainfall.

Infiltration will also affect the *quality* of the wastewater reaching the treatment plant. The amount of industrial wastewaters which are introduced into the municipal wastewater collection system will also affect the treatment efficiency of municipal plants. Therefore, these factors may account for some of the variations in the quantities of potential pollutants discharged by municipal plants in the different counties.

Many of the municipal wastewater treatment plants were not designed to treat the quantity of wastewater which now flows into the plant. Therefore, *they are overloaded and at best can only provide an effluent which is partially treated and of desired quality*. Many of the industrial wastewater treatment plants *require upgrading* in order to be able to effectively treat their particular wastewaters to a quality which meets water quality criteria.

It is interesting to note that the discharge of municipal wastewater in 30 of the 36 counties is less than 10,000,000 gallons per day (10 MGD) and of these 30 counties, 18 counties have municipal wastewater discharges of less than 3 MGD. Ten counties have a wastewater flow between 2 and 5 MGD while the wastewater flows in two counties is between 5 and 10 MGD. Three counties produce municipal wastewater flows between 10 and 20 MGD per day and the municipal wastewater flows in two counties is more than 20 MGD but less than 100 MGD. Almost 200 MGD of municipal wastewater is discharged in only one county.

These data are based on the information available on the wastewater discharge permits and the return flow data. In many of these counties, only a portion of the population is served by a wastewater collection system. The Texas Municipal League has reported the number of sewer connections in various cities; however, the population served is not directly correlatable to the number of connections. The remainder of the population in these counties are required to treat and dispose of the wastewaters in *individual septic tank systems*. The available information which deals with the number of septic tanks and used to treat wastewater in the Coastal Zone is sparse. The proximity of the ground water table to the ground surface in the Coastal Zone makes it possible for the discharge from the septic tank absorption field system to enter the shallow ground water and be carried directly into the surface waters with minimal additional treatment.

The information available on the number of people serviced by a municipal wastewater collection system is far from adequate. The results of an inventory compiled in 1968 by the Federal Water Pollution Control Administration indicate that *6,819,000 people in Texas were served by adequate municipal wastewater facilities, and the wastewater of 1,925,000 people had no treatment.* The percentage of the people in Texas who were served by less than adequate or no treatment facilities was *23.2 percent.* These numbers are based on the 1960 Bureau of Census population data. In some cases, an estimate of the population served in a particular county exceeds the preliminary census estimate of the 1970 population for that county. In other cases, the information available on the discharge permit application is not complete and an estimate of the population served is not readily available. Because of these discrepancies it is almost impossible to develop an accurate figure which relates the number of people in a particular county who have individual wastewater disposal systems, which consist of a septic tank and absorption field. In general, most of the municipal wastewater treatment plants in the counties in the Coastal Zone *require some upgrading* in order to discharge effluents which meet the water quality criteria established by the Texas Water Quality Board. The Federal Water Pollution Control Administration in their Cost of Clean Water series estimated the *projected cost to upgrade and construct municipal wastewater treatment facilities in Texas for fiscal years 1969-1973 to be $378,500,000.* The capital outlays needed total $323,600,000 and the operation and maintenance costs are estimated to be $72,200,000.

The industrial wastewater discharges summarized in Table 2 *do not include the wastewaters from feed lot operations but do include* *the return flows from power generation.** Of the 36 counties in the Coastal Zone, 14 counties have no industrial discharges. The quantity of wastewater discharged from industrial use is concentrated in Harris, Jefferson, Nueces, Orange, Galveston, Cameron, Victoria, Brazoria, Fort Bend, and Calhoun counties. These ten counties account for *99* percent of total industrial wastewater discharge in the Coastal Zone area. *The majority of this industrial wastewater flow is associated with the refining and petrochemical industries.* The quality of the industrial wastewater discharges is based on the information included on the permit application and in the return flow data which were made available by the Texas Water Quality Board in the form of a computer printout sheet. Where information relating the quality of the particular discharge to the flow was not available, these flow data were not included in calculating the total pollutional load generated in the various counties.

Some industrial wastewaters are difficult to treat and treatment to meet regulatory standards is considered to be economically unfeasible. These industrial wastewaters may be injected into subsurface porous strata. These wastes are merely stored below ground in strata which are sealed by impervious strata, thus isolated from usable underground water supplies or mineral resources.

Sedimentary rocks in the unfractured state generally can store large volumes of wastes. This group of rocks includes sandstones, limestones, and dolomites; unconsolidated sands are generally excellent disposal formations. Fractured strata should be avoided since vertical fissures may exist and the injected waste may travel vertically towards usable water supplies.

Disposal wells vary in depth from a few hundred feet to about 15,000 feet. The capacity of various wells ranges from less than 10 to more than 2000 gallons per minute. *Waste disposed of in injection wells includes streams containing acids, alkalies, chlorides, chromates, cyanides, high BOD wastes, nitrates, phosphates, radioactive wastes, and others which are difficult or more expensive to dispose of by other methods.*

The disposal system consists of a well and surface equipment such as pumps and pretreatment equipment which may be necessary to remove constituents of the waste which may interfere with subsurface disposal. Some of the details of the design of the injection tubing and the well are shown in Figure 3. A casing, generally of steel, is cemented in place to seal the disposal stratum from the other strata which were penetrated during the drilling of the well. An injection tube transports the waste from the surface to the disposal stratum. An oil or fresh water is used to fill the annular space between the injection stratum. By monitoring the pressure of fluid, leaks in the injection tube or damage to the casing can readily be detected.

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* *The report on Energy and Power includes a detailed discussion on the environmental effects of the alternate methods of power production.*

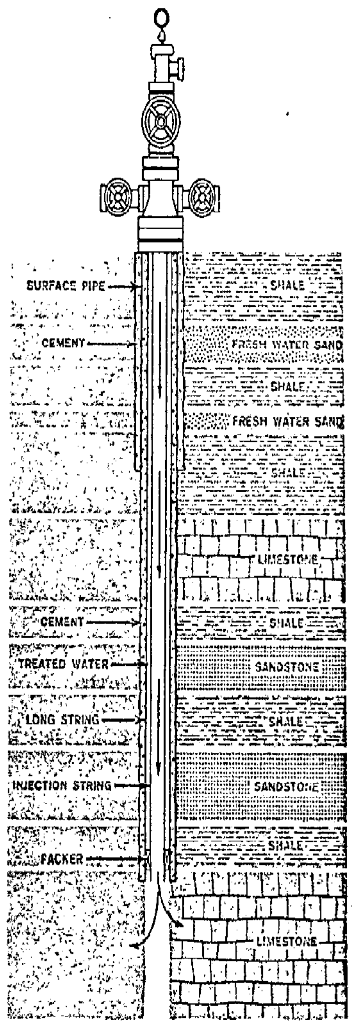


FIGURE 3

TYPICAL INJECTION WELL

The surface installation usually includes a storage pit or tank to level out variations in flow, equipment necessary for pretreatment of the waste and high pressure pumps. The degree of treatment required depends on the characteristics of the wastewater, the compatability of the formation water and the wastewater, and the characteristics of the receiving formation.

Injection wells are located in nine counties in the Coastal Zone. A total of *43 injection wells* which have been permitted are located in the Coastal Zone. Three of these permitted wells have not been installed. The number of wells and actual wastewater discharges are presented in Table 7 and Figure 4. The formations into which the industrial wastewaters are pumped are also listed in Table 7. The depth of the wells range from 3400 to 7650 feet below the ground surface. The permitted flow exceeds the actual flow being discharged into the injection well in some of the counties. This information regarding the total quantity of flow discharged into injection wells was obtained from the permit data available from the Texas Water Quality Board. No attempt was made to characterize the industrial wastewaters which were injected into the wells.

The total volume of industrial wastewaters disposed of in injection wells represents only a small fraction of the total quantity of industrial wastewater flow which is discharged into surface waters. Injection wells are located in those counties where the industrial activity is relatively high and where industrial wastewater flows far outshadow the amount of municipal wastewater flow which has been reported.

The discharge of *salt waters resulting from the exploration for natural gas and oil* into surface waters and ground waters can cause potential problems. The data presented in Table 8 and in Figure 5 indicate the quantity of salt water which must be disposed of in the various counties in the Coastal Zone. The method of salt water disposal is also shown in this table. These data were obtained from the Texas Water Development Board and are based on the result of a *1961* survey. Since this 1961 survey, *the Texas Railroad Commission has restricted the discharge of salt water into open pits and surface waters*. Therefore, based on this restriction, *no* salt water is presently discharged into surface water or into open unlined pits in the Coastal Zone. The results of a 1968 survey of salt water discharges were not available in a form that could be easily summarized in the limited time during which this inventory was compiled.

Solid Waste

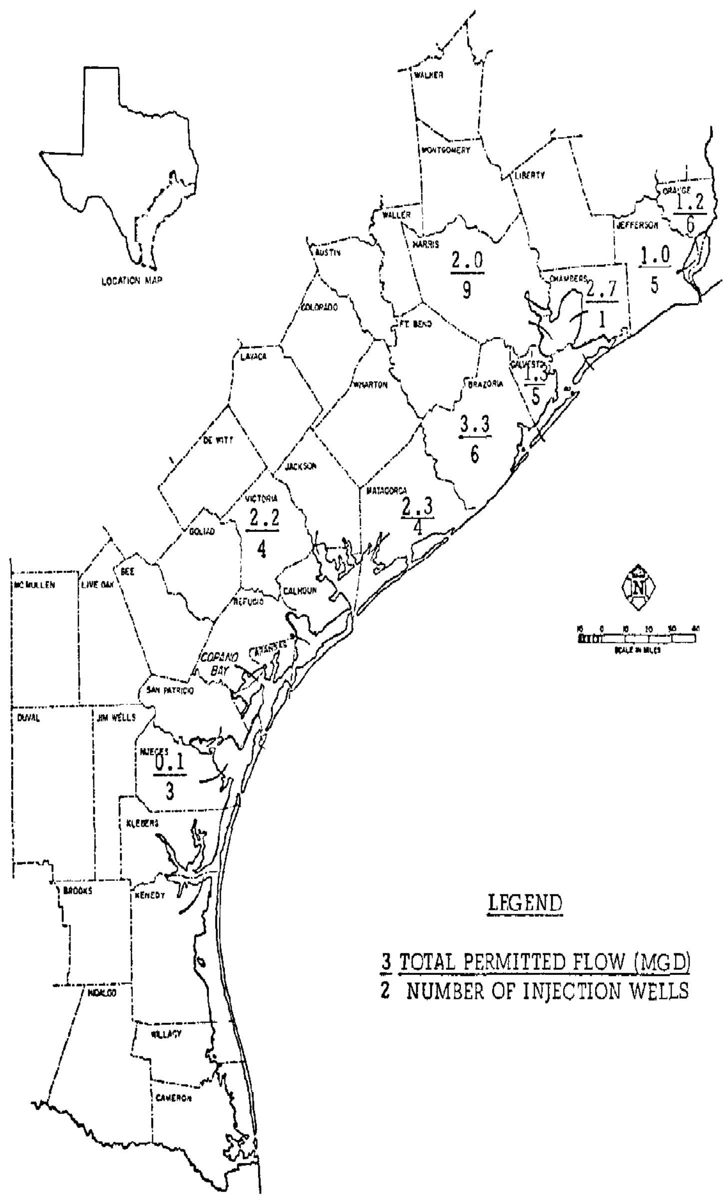
Solid wastes include a broad spectrum of materials which are no longer useful to man or for industrial purposes in their present form. A general classification of solid wastes which may be generated in a municipality is presented in Table 9. Most municipalities collect and dispose of *"ordinary refuse," "bulky waste,"* and in many cases, *"abandoned vehicles."* The extent to which municipal service is

TABLE 7

Wastewater Discharges into Injection Wells*

County	Number	Actual Flow (MGD)	Permitted Flow (MGD)
Brazoria	6	2.34	3.31
Chambers	1	------	2.69
Galveston	5	1.065	1.281
Harris	9	1.983	1.983
Jefferson	5	0.955	0.955
Matagorda	4	2.325	2.325
Nueces	3	0.019	0.091
Orange	6	1.239	1.239
Victoria	4	2.18	2.18
Formation			
Miocene	22	5.84	7.19
Pliocene-Miocene	7	2.64	2.64
Salt Dome	3	------	2.694
Sands	3	0.552	0.552
Sandstone	4	2.18	2.18
Frio	4	1.151	1.151

*Texas Water Quality Board



WASTE DISPOSAL WELLS (1970)

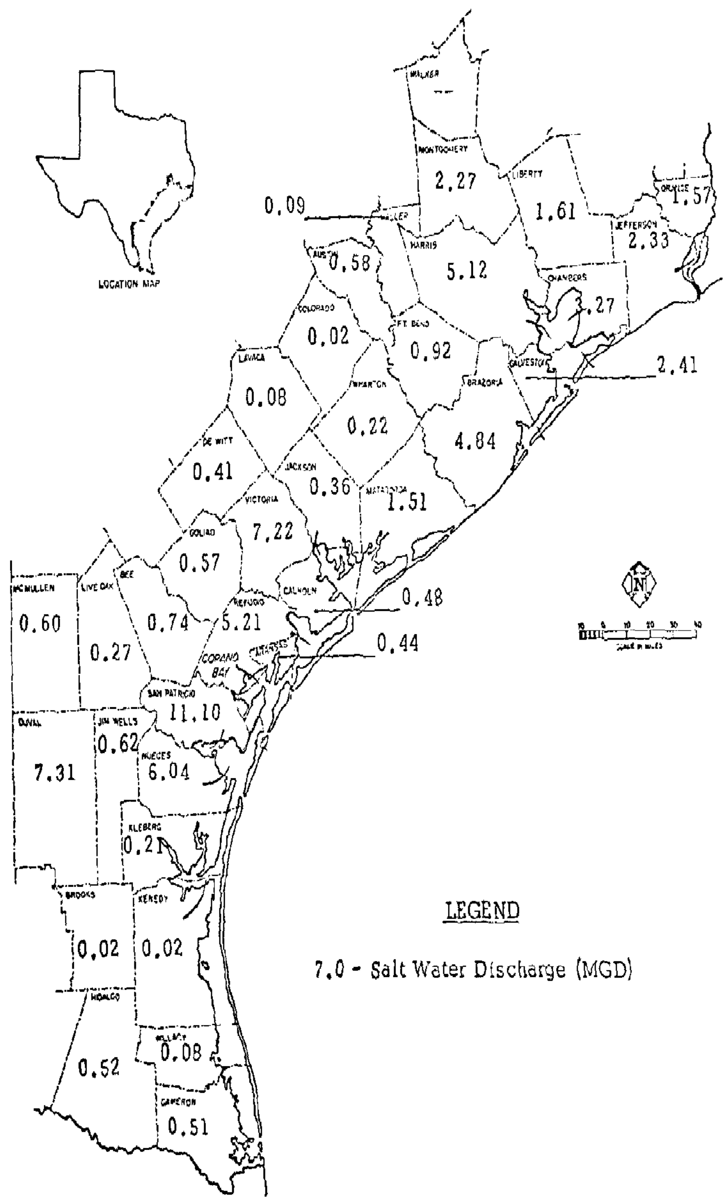
FIGURE 4

TABLE 8

Salt Water Discharges* (1961)
(Million Gallons Per Day)

County	Injection Wells	Open Pits	Surface Water	Other	Total
Aransas	--	0.20	0.24	--	0.44
Austin	0.56	0.02	--	--	0.58
Bee	0.43	0.31	--	<0.01	0.74
Brazoria	4.62	0.22	--	<0.01	4.84
Brooks	<0.01	0.01	--	<0.01	0.02
Calhoun	0.11	0.29	0.08	<0.01	0.48
Cameron	--	0.51	--	--	0.51
Chambers	1.82	0.24	1.19	0.02	3.27
Colorado	<0.01	<0.01	--	<0.01	0.02
De Witt	0.19	0.22	--	--	0.41
Duval	5.19	2.06	--	0.06	7.31
Fort Bend	0.77	0.14	0.01	--	0.92
Galveston	1.07	0.28	1.04	0.02	2.41
Goliad	0.43	0.14	--	--	0.57
Harris	2.08	0.70	2.33	0.01	5.12
Hidalgo	0.04	0.16	0.32	--	0.52
Jackson	0.26	0.04	0.06	<0.01	0.36
Jefferson	1.76	0.17	0.39	0.01	2.33
Jim Wells	0.30	0.32	--	<0.01	0.62
Kenedy	0.01	--	<0.01	--	0.02
Kleberg	--	0.19	0.02	<0.01	0.21
Lavaca	0.05	0.03	--	--	0.08
Liberty	1.35	0.20	0.06	<0.01	1.61
Live Oak	0.01	0.26	--	<0.01	0.27
Matagorda	1.37	0.14	--	<0.01	1.51
McMullen	--	0.60	--	--	0.60
Montgomery	1.97	0.09	--	0.21	2.27
Nueces	1.40	1.98	2.64	0.02	6.04
Orange	0.07	0.58	0.92	--	1.57
Refugio	2.68	1.54	0.99	--	5.21
San Patricio	0.88	2.93	7.27	0.02	11.10
Victoria	5.98	1.23	--	0.01	7.22
Walker	--	--	--	--	--
Waller	0.09	<0.01	--	--	0.09
Wharton	0.20	0.01	<0.01	<0.01	0.22
Willacy	0.01	0.06	--	<0.01	0.08

* Texas Water Development Board (1961)



SALT WATER DISCHARGE WELLS (1961)

FIGURE 5

TABLE 9

CLASSIFICATION OF SOLID WASTES

A. Ordinary Refuse

1. Garbage includes animal and vegetable residue resulting from the preparation, cooking and eating of food. This material is readily decomposed and is generally the cause of the foul odors associated with domestic solid wastes.

2. Rubbish or trash includes all other materials which are generally discarded by a homeowner, resident, small business, commercial establishment or restaurant. A portion of this material is burnable.

3. Yard trimmings include debris from cutting lawns, pruning etc., but excludes branches longer than 3 feet in length and tree stumps.

4. Small dead animals includes, dogs, cats, squirrels, etc. which are accidentally killed on public streets or roads.

5. Street refuse - litter from receptacles.

B. Bulky or Oversized Wastes

Discarded stoves, refrigerators or other large appliances and sofa, stuffed chairs or other large pieces of furniture, as well as, large branches, fallen trees, and tree stumps.

C. Abandoned Vehicles

D. Industrial Wastes

E. Demolition Wastes

F. Construction Wastes

G. Hospital Wastes

H. Hazardous Wastes

Include explosive toxic or radioactive liquids and solids

I. Water and Wastewater Treatment Plant Sludges provided to small businesses, restaurants, commercial establishments and industry is determined by the policy established by individual municipality or local government.

The composition of ordinary municipal refuse is presented in Table 10. It is interesting to note that *paper and paper products constitute about 40 percent of the weight of the refuse and that garbage constitutes only ten percent of the weight.* The use of household disposal units will reduce the quantity of garbage that enters the refuse collection system but will increase the load of suspended solids which must be handled at the municipal wastewater treatment plant. The relative percentage of glass, paper, metals, and plastics will depend on the packaging industry, although based on present trends an increase in the quantity of paper and paper products can be expected.

The solid waste production data for the Coastal Zone is presented in Table 11 and Figure 6. These data were obtained from the Texas State Department of Health and represent the results of a 1968 survey. The quantity of refuse collected by municipal and private vehicles and disposed of in municipal, county, and privately owned disposal sites are based on estimates provided by the municipal and county official and disposal site operators.

The amount of industrial solid wastes which are collected by private organizations are generally not included in these lists. Some of the private collectors can dispose of solid waste in municipal or county disposal facilities do not accept sludges, industrial solid wastes, or hazardous solid wastes.

The amount of refuse generated daily per person is also shown in Table 11. This number is based on the total estimated quantity of refuse collected annually divided by the estimated population served. Refuse collection vehicles are not routinely weighed in most areas; therefore, the weight of refuse collected is merely a guess. Since this per capita production rate is based on two estimated figures, *the specific value for each county varies considerably from the next.*

The per capita refuse production varies from *a minimum of 0.69 pounds per capita per day to a maximum of 13.2 pounds per capita per day*. The average production rate for the Coastal Zone based on the total estimated population served and the total estimated quantity of refuse collected is *5.12 pounds per capita per day*. This value compares well with the value of 5 pounds per capita per day which is normally accepted as a reasonable rate of refuse production. Adequate records of the actual weight of the refuse collected daily is required in each county if a reasonable estimate of the per capita production is to be available for future planning of a solid waste management program. Other solid wastes which are not included in the ordinary municipal refuse which require disposal are also listed in Table 11. Abandoned automobiles pose serious

TABLE 10

COMPOSITION OF ORDINARY MUNICIPAL REFUSE

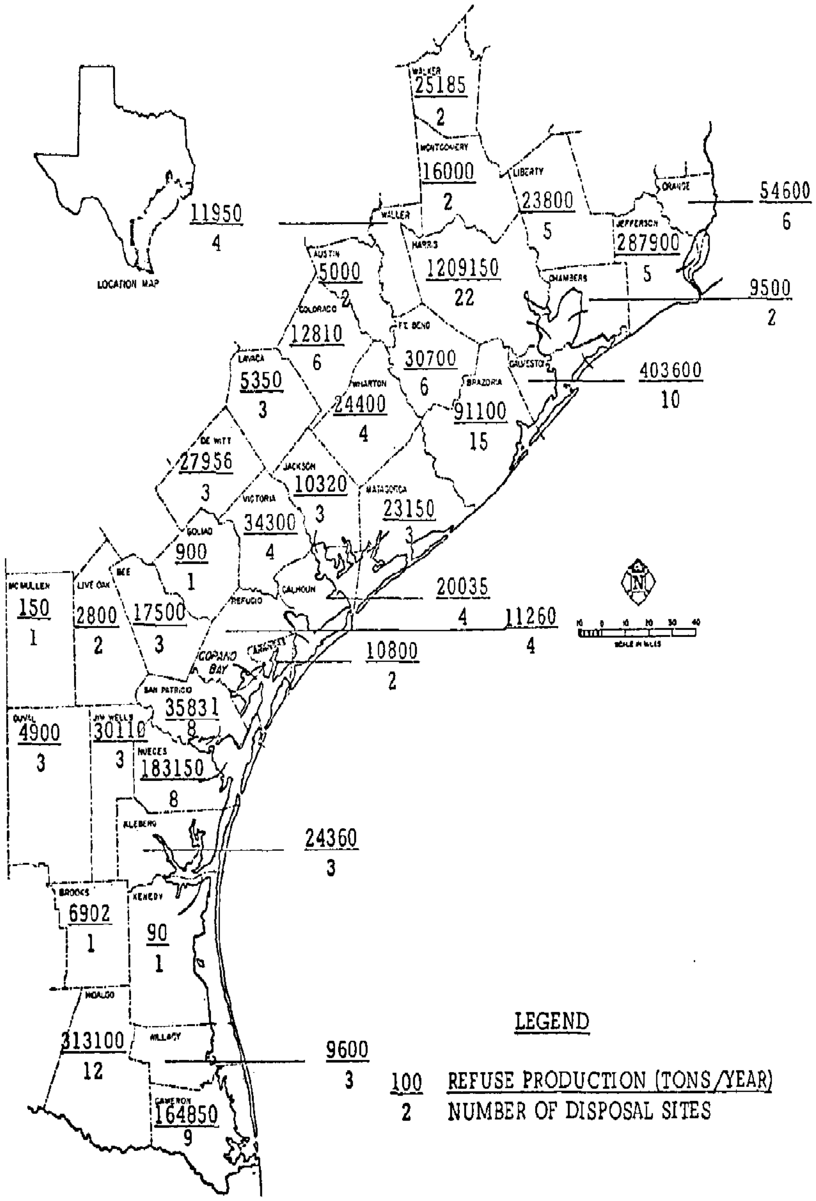
Component	Weight Percent
Paper	40
Garbage	10
Other Combustibles textile plastics fats, etc. grass tree limbs	25
Inerts glass ceramics stones metals ash	25

TABLE 11

Solid Waste Production*

County	Population Served	Tons/year	Quantity Pounds/capita/day
Aransas	9,600	10,800	6.2
Austin	14,300	5,000	1.9
Bee	23,500	17,500	4.1
Brazoria	106,000	91,100	4.7
Brooks	9,000	6,902	4.0
Calhoun	20,200	20,035	5.5
Cameron	134,900	164,850	6.7
Chambers	12,200	9,500	4.3
Colorado	18,500	12,810	3.8
De Witt	19,800	27,956	7.7
Duval	13,700	4,900	2.0
Fort Bend	51,300	30,700	3.3
Galveston	168,600	403,600	13.2
Goliad	5,000	900	1.0
Harris	1,597,800	1,209,150	4.1
Hidalgo	177,100	313,100	9.7
Jackson	14,100	10,320	4.0
Jefferson	247,600	287,900	6.4
Jim Wells	31,500	30,110	5.2
Kenedy	700	90	0.7
Kleberg	30,900	24,360	4.3
Lavaca	19,700	5,350	1.5
Liberty	32,500	23,800	3.7
Live Oak	7,200	2,800	2.1
Matagorda	31,700	23,150	4.0
McMullen	1,200	150	0.7
Montgomery	46,400	16,000	1.9
Nueces	232,500	183,150	4.3
Orange	72,900	54,600	4.1
Refugio	10,200	11,260	6.0
San Patricio	47,200	35,831	4.2
Victoria	56,800	34,300	3.3
Walker	28,500	25,185	4.9
Waller	14,700	11,950	4.4
Wharton	39,600	24,400	3.4
Willacy	14,600	9,600	3.6

*Texas State Department of Health (1968)



REFUSE PRODUCTION (1968)

FIGURE 6

problems to most municipalities. The results of a 1966 study of Solid Waste Production in Selected Texas Cities indicate that 1.6 passenger vehicles were abandoned for each 1,000 people. Therefore one could expect that about *6,7000 automobiles* will be abandoned in the Coastal Zone during 1970.

The sludge and residues resulting from the treatment of water for municipal supply and industrial use as well as from the treatment of municipal and industrial wastewaters also present a solid waste disposal problem. The quantity of sludge produce during treatment of water is affected by the quality of raw water supply, the chemicals added, the degree of treatment required to make the water suitable for municipal water supply, or for the specific industrial purpose. The water treatment sludges generally contain chemical precipitates and the sludges are difficult to concentrate but do not contain sufficient quantities of putrescible organic material; therefore, very little offensive odors are associated with these sludges. The characteristics of the wastewaters and the degree of treatment required will effect the quantity of sludge which is generated during the treatment of municipal and industrial wastewaters. These wastewater sludges generally contain putrescible organic material which readily decompose resulting in obnoxious odors. Therefore, these sludges require some type of treatment and disposal facilities at different treatment plants will vary. The residual solids may be buried or placed on the land as a soil conditioning agent. *Therefore the disposal of the solid residue and sludges from the treatment of wastewaters may result in pollution of ground and surface waters if improperly disposed of on land and air pollution if proper air cleaning is not furnished during incineration.*

The characteristics of industrial solid wastes are as varied as the industries located in the Coastal Zone. A very limited amount of information regarding the characteristics of the industrial solid waste is available. The staff of the Texas Water Quality Board is actively engaged in surveying the solid wastes generated at industrial facilities. The results of this survey, when completed, should provided qualitative and quantitative data for various types of industries.

Most industrial plant sites will store the sludges from water and wastewater treatment in lagoons on the plant site, if land is available. Otherwise these residues and other semi-solid residues are hauled off for disposal by private collectors. Most of the combustible residues in solid waste in industrial plant sites are incinerated at the plant site or collected by a private collection agency for disposal at some other site.

Disposal of municipal solid waste in the counties in the Coastal Zone is primarily on the land. The number of solid waste disposal sites reported in the Coastal Zone totals 175. This total includes four incinerator sites, three of which are in Harris County and one in Hidalgo County. One compost plant has also been reported in

Harris County. The remaining refuse disposal sites include sanitary landfills and open dumps. *Of the 175 number of land disposal sites, only 13 are considered to be sanitary landfills.* The remainder of the land disposal sites are considered to be *substandard landfills* generally characterized by uncontrolled burning of refuse, improper covering of the refuse at the end of the day, presence of rats and flies, drainage of runoff to surface water, blowing paper, and odors.

It should be pointed out that this information is based on a survey which was conducted by the Texas State Department of Health in 1968. Therefore, the number of disposal sites may have increased during this time and some of the dumps converted to sanitary landfills. The information available indicates that none of the incinerators plants for the disposal of refuse are presently in operation. The one operating compost plant which handled about 350 tons of refuse per day for the city of Houston in Harris County, has recently been shut down since *the market for reclaimed materials was a casualty of the economic slowdown.*

A sanitary landfill includes the placement of the refuse on the ground or in a prepared trench and compacted with a catepillar bulldozer or similar equipment. The compacted refuse is covered at the end of each operating day with about six inches of compacted soil. No burning of the refuse is permitted at the landfill site and proper drainage of the site is provided.

The pollution of ground water by refuse in sanitary landfills can take place only if the following conditions exist:

(a) the sanitary landfill is directly above or adjacent to an aquifer,

(b) the refuse in the sanitary landfill becomes supersaturated because of percolation of rainfall, pooling of surface water, or flow of ground water, and

(c) leached fluids are produced and the leachate enters the aquifer.

The geology, topography and ground water and surface water resources at the proposed sanitary landfill site should be carefully evaluated.* The site which provided the least potential for water pollution should be selected.

Refuse in sanitary landfill can absorb an extraordinary amount of water before supersaturated conditions develop and leachate is produced. Paper itself can absorb two to three times its weight in water. Leachate was produced only after 15 inches of water was

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* *The Bureau of Economic Geology has recently completed a study of the coastal region in which they identified potential landfill sites.*

continually applied at the rate of one inch per day to a fill in a ten-foot deep bin. The quantity of waste required to produce a leachate was about 25 gallons per cubic yard of fill or about 65 gallons per ton of refuse.

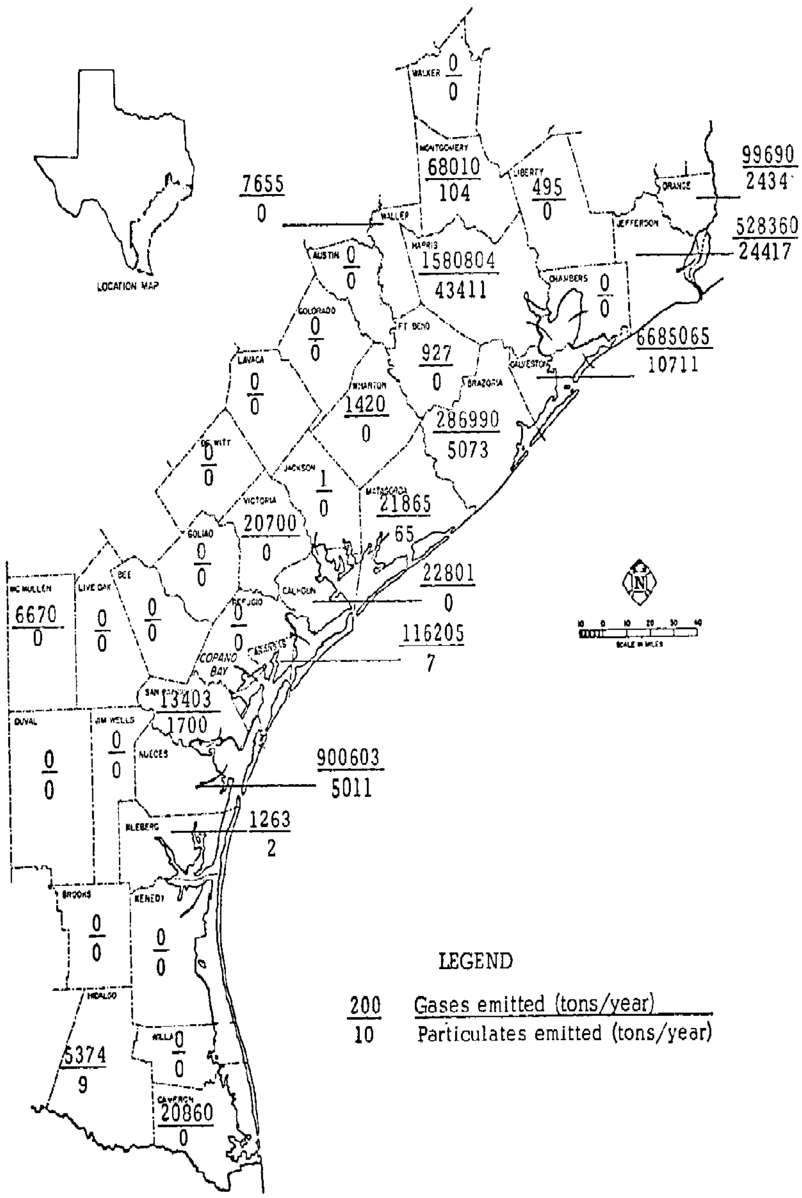
The overall picture of water pollution from a sanitary landfill is quite complex. The chances of water pollution can be minimized by locating the sanitary landfill away from ground water aquifers and surface water supplies. Proper draining of the site to avoid supersaturation of the refuse in the sanitary landfill is also necessary to eliminate production of leachate.

Open burning of refuse at dumps also *contributes to the particulate and gaseous emissions* to the atmosphere which constitute air pollution. The organic material in the refuse provides a good *breeding place for flies.* In the warm summer months, the time for flies to develop from the egg stage to adult is about 5 to 7 days. Although flies have not been directly incriminated with the transmission of diseases from refuse to humans, the flies are a nuisance. The garbage in the refuse also provides a *source of food for rats.* Therefore, an open dump is generally infested with rats which in turn can migrate from the dump to adjacent housing. Water that accumulates in discarded containers provides a *breeding place for mosquitoes* which in turn are vectors for the transmission of diseases such as encephalities, malaria, and yellow fever. Of these diseases, encephalitis is probably the most common and of most concern in the Coastal Zone.

Air Pollution

The gaseous and particulate emissions from industrial activities are presented in Table 12. *These emissions to the atmosphere do not include the particulate material and gases generated during the uncontrolled burning of refuse in open dumps, nor the emissions from motor vehicles.* The data in Table 12 were obtained for surveys conducted by the Texas Air Control Board and are expressed in terms of tons per year. The industrial gaseous emissions into the atmosphere include nitrogen oxides, sulfur oxides, hydrocarbons, carbon monoxide, hydrogen sulfide, sulfuric acid, flourides, and other compounds. Water vapor is also gaseous but is considered relatively harmless and not an air pollutant in the same sense as chemical compounds. The particulate and gaseous emissions into the atmosphere are also presented in Figure 7. There are not industrial emissions into the atmosphere in 14 of the counties in the Coastal Zone. Industrial gases are emitted in 21 counties, while particulate material and gases are reported to be emitted in only 12 counties.

The data presented in Table 12 indicate that the industrial counties account for the bulk of the atmospheric emissions. On a weight basis the industrial gaseous emission exceed the industrial particulate emission by a wide margin. More than *11,300,000 tons per year of industrial gaseous emissions* excluding water vapor and more than *92,000 tons per year of particulate emissions* have been reported



Industrial Emissions to the Atmosphere

Figure 7

TABLE 12

INDUSTRIAL AIR POLLUTION EMISSIONS*
(TONS/YEAR)

County	Gases	Particulates	Water Vapor
Aransas	116205	7	532000
Austin	0	0	0
Bee	0	0	0
Brazoria	286990	5073	35584194
Brooks	0	0	0
Calhoun	22801	0	3020000
Cameron	20860	0	523000
Chambers	0	0	3716
Colorado	0	0	0
DeWitt	0	0	0
Duval	0	0	0
Fort Bend	927	0	428008
Galveston	6685065	10711	13740000
Goliad	0	0	0
Harris	1580804	43441	296465702
Hidalgo	5374	9	439290
Jackson	1	0	0
Jefferson	528360	24417	19400000
Jim Wells	0	0	0
Kenedy	0	0	0
Kleberg	1263	2	13140
Lavaca	0	0	0
Liberty	495	0	50000
Live Oak	0	0	0
Matagorda	21865	65	3457650
McMullen	6670	0	0
Montgomery	68010	104	1892149
Nueces	900603	5011	21832105
Orange	99690	2434	14740482
Refugio	0	0	0
San Patricio	13403	1700	4124300
Victoria	20700	0	5000000
Walker	0	0	0
Waller	7655	0	4777936
Wharton	1420	0	122000
Willacy	0	0	0

*Texas Air Control Board (1970)

for the Coastal Zone. The relatively low amount of particulate material in the industrial emissions may be attributable to the fact that most industries burn natural gas which results in fewer particles than other fossil fuels. Enforcement of the Air Pollution Control legislation relating to particulate emissions may also be responsible for the relatively low quantity. Gaseous emissions are more difficult to remove and in most cases are not visible; therefore, the gases go by unnoticed except for any odors or colors associated with the gases.

Each industry has characteristic emissions which are unique to an industrial category or classification. Some typical emissions for industrial and agricultural activities are summarized in Table 13. The quantity and quality of gaseous and particulate emissions is related to the raw material used, the process applied and the effectiveness of the air pollution control equipment which is installed, if in fact any air cleaning devices are used.

The industrial emissions have the most direct effect on the environment immediately adjacent to the source of the emissions. In many cases the industrial emissions to the atmosphere are manifested by visible plumes at plant sites. This dramatic emission of colored plumes, particulate materials and chemical mists, etc., may travel some distance and affect the health and property of individuals at relatively remote locations. Odors may be the principle indicator of industrial emissions when no plume is obvious.

Motor vehicles also contribute to the emissions to the atmosphere. An inventory of the number of motor vehicles registered in the various counties in the Coastal Zone is presented in Table 14. The motor vehicles are classified in the following categories: passenger vehicles, trucks, buses, motorcycles, and a category including truck tractors, tractors, construction machinery, etc. The number of vehicles in the Coastal Zone which have exempt registration is not included. The distribution of passenger vehicles among the population in the Coastal Zone expressed as registered passenger vehicles per person is presented in Table 15 and Figure 8. The ratio does not vary significantly and covers a range of 0.28 to 0.49 registered passenger vehicles per person. The average for the Coastal Zone is 0.40 passenger vehicles per person. The population density is higher in the urban industrial counties and the total number of passenger vehicles is also high in these counties. Therefore the automobile emissions add to the industrial gaseous and particulate emissions.

The major components of automobile emissions are shown in Table 16 and include *carbon monoxide, hydrocarbons, oxides of nitrogen, oxides of sulfur, and particulate material.* The particulate material includes carbon particles, lead particles, and condensates which are discharged in the exhaust. The characteristics and quantity of automobile exhaust are a function of the speed of the vehicles and data in Table 16 are based on an average speed of 25 miles per hour.

TABLE 13

CLASSIFICATION OF INDUSTRIAL EMISSIONS

Type of Industry	Emissions
Chemical Industry	
Ammonia Plant	Ammonia fumes, carbon monoxide
Chlorine Plant	Chlorine, gas, liquid chlorine, mercury
Nitric Acid Plant	Nitric Oxide, nitrogen dioxide, acid mist
Paint and Varnish	Fumes, aldehydes, ketones
Manufacturing	Phenols, terpenes, particulates
Phosphoric Acid Plants	P_2O_5 Acid mist, nitrogen oxides
Phosphoric Acid	Gaseous fluorides
Fertilizer Plant	Silicon tetrafluoride, hydrogen fluoride
Sulfuric Acid Plant	Sulfur dioxide, acid mist
Food and Fiber Industry	
Cotton Ginning	Particulates, dust
Coffee Roasting	Particulates, smoke, odors
Feed and Grain Mills	Dust
Metallurgical Industry	
Aluminum Ore Reduction	Particulate alumina, carbon and fluorides, gaseous fluorine
Copper Smelters	Carbon monoxide, sulfur oxides, nitrogen oxides and fine particulate fume
Iron and Steel Mills	Particulates, fumes, smoke, particulate lead fumes
Lead Smelters	Lead fumes, sulfur dioxide
Zinc Smelters	Particulates, fumes, sulfur dioxide

TABLE 13
(con'd.)

Secondary Metals Industry	
Ferrous Metals	Particulates
Aluminum	Fine Particulates, gaseous chlorine and fluorine
Brass and Bronze Smelting	Particulates, zinc oxide fumes
Gray Iron foundary	Particulates
Lead Smelting	Particulates, sulfur compounds
Magnesium Melting	Particulates
Zinc Processes galvanizing, calcining smelting and sweating	Particulates
Mineral Products Industry	
Asphalt Roofing	Particulates, oil mist
Asphaltic Concrete Plant	Particulates
Calcium Carbide Plant	Acetylene, sulfur dioxide sulfur trioxide, particulates
Cement Plant	dust
Concrete Batch Plant	Particulates
Frit Manufacturing Plant	Particulates, condensed metallic fumes, fluorides
Glass Manufacturing Plant	Particulates, fluorides
Lime Manufacturing Plant	Particulates
Insulation Manufacturing Plants	Asbestos fiber, rock wool fibers
Petroleum Refinery	Hydrocarbons, particulates, nitrogen dioxide, carbon monoxide, aldehydes, ammonia
Plastics	Ethylene, methacrylate
Petrochemical Plants	Losses of intermediate and final product
Pulp and Paper Industry	Particulates, Hydrogen sulfide, methyl mercaptan, dimethyl sulfur
Dry Cleaning Plants	Chlorinated hydrocarbons, tetrachloroethylene, petroleum solvents, hydrocarbon vapors

TABLE 13
(con'd.)

Metal Scrap Yards	Smoke, soot
Rendering Plant	Organic vapors, odors
Agricultural Activities	
Crop spraying and dusting	Organic phosphates, chlorinated hydrocarbons, arsenic and lead
Field Burning	Smoke, flyash, soot
Refuse Incineration	Particulates, flyash
Open Dump Refuse Burning	Particulates, odors, hydrocarbons, smoke

TABLE 14

REGISTERED VEHICLES (1970)*

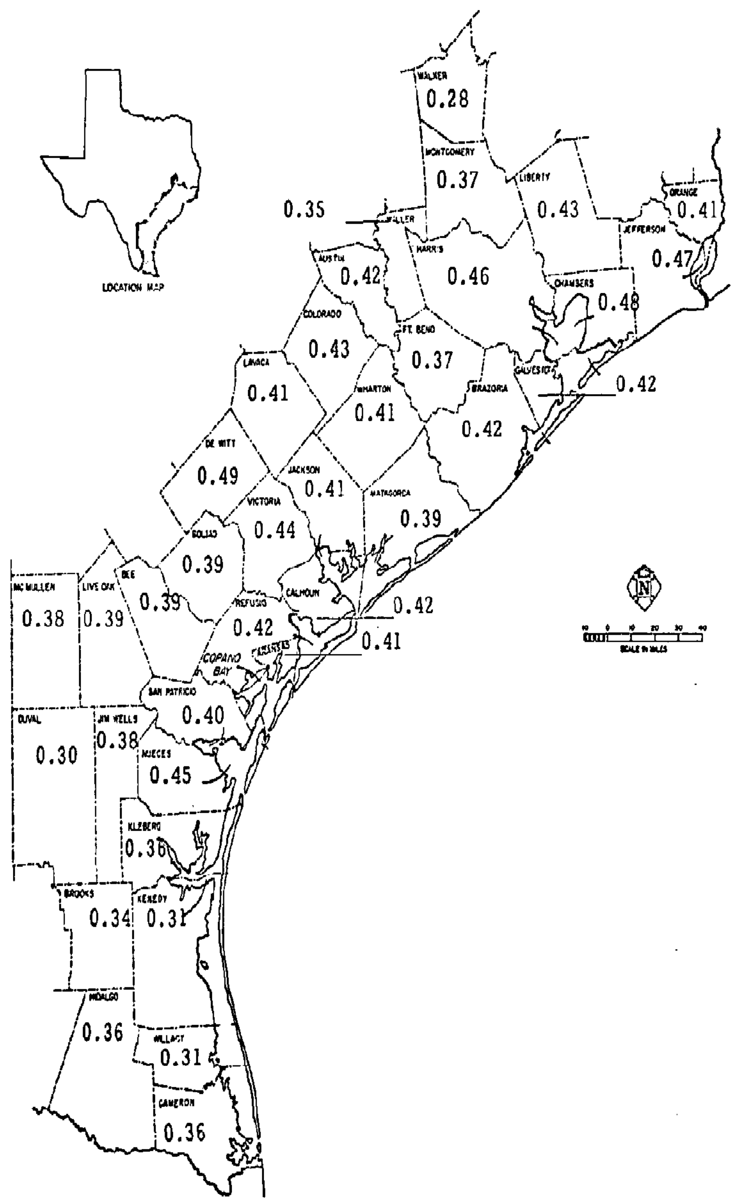
County	Passenger	Trucks	Buses	Motor Cycles	Others
Aransas	3432	1027	0	56	49
Austin	5573	2867	0	60	137
Bee	8620	2718	0	220	127
Brazoria	45085	14984	0	1105	456
Brooks	2643	378	0	25	48
Calhoun	7124	2315	0	165	78
Cameron	50099	12363	117	957	658
Chambers	5813	3936	0	53	476
Colorado	7387	3915	0	88	215
DeWitt	8705	3406	0	94	139
Duval	3403	1702	0	38	43
Fort Bend	18930	6544	0	251	289
Galveston	70214	15179	96	1514	549
Goliad	1778	881	0	19	18
Harris	796310	152919	472	16521	10547
Hidalgo	62817	19244	4	1029	959
Jackson	5168	2592	0	72	117
Jefferson	113815	23968	42	2227	1179
Jim Wells	12145	4324	2	183	264
Kenedy	204	102	0	1	2
Kleberg	11507	2671	0	419	364
Lavaca	7207	3160	0	417	94
Liberty	13192	6692	0	263	324
Live Oak	2435	1507	0	19	49
Matagorda	10909	4328	7	139	122
McMullen	398	320	0	8	17
Montgomery	17149	8213	0	497	250
Nueces	105038	20782	1	2034	1962
Orange	29012	8161	0	483	118
Refugio	3863	1562	0	59	68
San Patricio	17691	5664	0	232	247
Victoria	23502	6129	0	596	425
Walker	6910	2763	0	155	83
Waller	4942	2646	0	60	47
Wharton	14767	6009	0	178	264
Willacy	4855	2177	0	61	86

*Texas State Highway Department (1970)

TABLE 15

POPULATION AND PASSENGER VEHICLE DENSITIES (1970)

County	Population/Sq. Mi.	Vehicles/Person
Aransas	33.1	0.41
Austin	20.9	0.42
Bee	25.6	0.39
Brazoria	75.0	0.42
Brooks	8.2	0.34
Calhoun	33.8	0.42
Cameron	144.2	0.36
Chambers	15.4	0.48
Colorado	18.2	0.43
DeWitt	58.0	0.49
Duval	6.5	0.30
Fort Bend	58.4	0.37
Galveston	415.9	0.42
Goliad	5.3	0.39
Harris	1006.0	0.46
Hidalgo	107.9	0.36
Jackson	15.3	0.41
Jefferson	254.7	0.47
Jim Wells	36.9	0.38
Kenedy	0.5	0.31
Kleberg	38.6	0.36
Lavaca	19.3	0.41
Liberty	26.5	0.43
Live Oak	6.1	0.39
Matagorda	24.7	0.39
McMullen	0.9	0.38
Montgomery	43.3	0.37
Nueces	284.2	0.45
Orange	188.0	0.41
Refugio	11.6	0.42
San Patricio	59.3	0.40
Victoria	57.2	0.44
Walker	30.9	0.28
Waller	27.0	0.35
Wharton	33.8	0.41
Willacy	25.4	0.31



NUMBER OF MOTOR VEHICLES
REGISTERED PER PERSON (1970)

FIGURE 8

TABLE 16

Characteristics of Automobile Exhausts*

Emission	Quantity pounds per 1000 vehicle-miles 1966	1968**	1970**
Carbon Monoxide	165.0	15.0	10.4
Hydrocarbons	12.5	1.5	1.0
Oxides of Nitrogen	8.5	-----	----
Oxides of Sulfur	0.6	-----	----
Particulates	0.8	-----	----

*Duprey, R. L., Compilation of Air Pollutant Emission Factors, National Center for Air Pollution Control, Durham, North Carolina, 1968.

**Air/Water Pollution Report, January 29, 1968.

NOTE:

1966 - typical emissions of automobiles produced before 1966

1968 - typical emissions of 1968 model year automobiles with mandatory air pollution control devices installed

1970 - typical emissions of 1970 model year automobiles with air pollution control devices installed

The information shows typical emissions in the exhaust of automobiles produced before 1966 on which no air pollution control devices were installed as well as for passenger vehicles on which the mandatory air pollution control devices were installed. The air pollution control devices installed on the 1970 model year vehicles should reduce the quantities of carbon monoxide and hydrocarbons from *15.0 to 10.4* pounds per vehicle mile and from *1.5 to 1.0* pounds per vehicle mile, respectively.

The quantity of gaseous emissions from automobile exhausts in the Coastal Zone would be about *1,000,000 tons per year.* Comparatively speaking, industrial emissions in the Coastal Zone exceed 11,000,000 tons per year. This estimate is based on the fact that one-third of the vehicles in the Coastal Zone were equipped with air pollution control devices to meet the standards set during 1968 and 1970, and the fact that each of the passenger vehicles were driven for 10,000 miles during the year. As the number of older vehicles are replaced by those vehicles with effective air pollution control devices pollutant emissions to the atmosphere will be markedly reduced. However, the disposal of the abandoned vehicles could lead to a solid waste handling and disposal problem.

The gaseous and particulate emissions from those vehicles which use diesel fuel must also be included in the inventory. The characteristics of the emissions from vehicles burning diesel fuel is summarized in Table 17. The emissions to the atmosphere from aircraft also contribute to the total air pollution inventory. *Typical emissions for aircraft* are summarized in Table 18.

The cotton ginning operation is characterized by emissions of particulate material and gases into the atmosphere. Cotton gins are located in 18 counties in the Coastal Zone. The counties in which cotton gins are located and the quantity of cotton processed are presented in Table 19. The quantity of particulate emissions resulting from the ginning operation is also presented in this table. Approximately 11.7 pounds of particulates are generated from each bale of cotton processed. It should be noted, however, that the cotton ginning operation has been declining in the Coastal Zone. Therefore, cotton gins as sources of air pollution should also be on a decline.

Animal Waste

The production of animals such as beef cattle, milk cows, hogs, sheep and lambs, chickens, and turkeys present a solid waste management problem and can be the source of water pollution. The number of animals produced in the various counties in the Coastal Zone are summarized in Table 20. The source of this information is the U.S. Census of Agricultural, 1964.

A number of the counties in the Coastal Zone rank among the top ten counties in Texas in the production of particular animals. Five counties in the Coastal Zone are among the top ten counties in Texas

TABLE 17

Characteristics of Motor Vehicle Exhausts*

Emission	Quantity pounds per 1000 gallons of fuel: Automobiles (gasoline)	Diesel Engines
Carbon Monoxide	2300	60
Hydrocarbons	200	136
Oxides of Nitrogen	113	222
Oxides of Sulfur	9	40
Particulates	12	110

*Duprey, R. L., Compilation of Air Pollutant Emission Factors, National Center for Air Pollution Control, Durham, North Carolina, 1968.

TABLE 18

Characteristics of Aircraft

Exhaust Below 3500 Feet*
(pounds per flight**)

Emission	Jet Aircraft (per engine)		TurboProp		Piston Engine	
	Conventional	Fan Jet	2 Engine	4 Engine	2 Engine	4 Engine
Carbon Monoxide	8.75	5.15	2.0	9.0	134.0	326.0
Hydrocarbons	2.50	4.75	0.3	1.2	25.0	60.0
Oxides of Nitrogen	5.75	2.30	1.1	5.0	6.3	15.4
Particulates	8.5	1.85	0.6	2.5	0.6	1.4

*Duprey, R. L., Compilation of Air Pollutant Emission Factors, National Center for Air Pollution Control, Durham, North Carolina, 1968.

**Flight is defined as a combination of a landing and a take-off.

TABLE 19

COTTON GINNING*

County	Bales Ginned From 1966 Crop	Particulate Emissions pounds
Austin	6,971	81,561
Bee	4,485	52,475
Brazoria	4,504	52,697
Calhoun	5,562	65,075
Cameron	108,805	1,273,019
Colorado	5,934	69,428
Fort Bend	24,006	280,870
Hidalgo	98,867	1,156,744
Jackson	2,886	33,766
Jim Wells	8,113	94,922
Lavaca	7,692	89,996
Matagorda	4,304	50,357
Nueces	66,624	779,501
Refugio	9,586	112,156
San Patricio	59,161	692,184
Victoria	6,632	77,594
Wharton	30,723	359,459
Willacy	42,217	493,939

*U.S. Bureau of Census Reports

TABLE 20

ANIMAL PRODUCTION*

County	Cattle	Milk Cows	Hogs	Sheep Lambs	Chickens	Turkeys
Aransas	2,392	11	139	130	1,384	3
Austin	83,498	2,361	6,373	2,270	134,703	2,244
Bee	37,009	539	1,714	483	29,373	137
Brazoria	98,388	2,149	4,416	839	120,395	393
Brooks	39,768	1,389	134	72	44,384	40,049
Calhoun	13,208	76	115	468	6,314	163
Cameron	25,780	1,771	1,821	290	68,965	422
Chambers	46,879	51	408	330	16,312	111
Colorado	86,641	1,904	4,434	1,314	235,906	18,649
DeWitt	76,859	3,965	7,113	3,669	93,855	173,122
Duval	47,767	3,844	367	205	4,976	212
Fort Bend	74,451	1,038	5,047	730	104,001	4,837
Galveston	17,711	2,154	447	170	209,453	259
Goliad	44,670	224	5,978	1,902	17,118	2,389
Harris	95,829	13,190	4,964	1,259	344,948	575
Hidalgo	76,296	3,244	5,057	234	115,651	4,147
Jackson	59,176	355	1,569	739	25,223	627
Jefferson	45,813	533	376	280	15,052	213
Jim Wells	51,099	9,181	1,479	442	40,872	20,271
Kenedy	26,787	92	4	---	43	---
Kleberg	72,567	715	4,828	320	18,898	878
Lavaca	81,670	4,092	10,639	2,542	214,768	144,778
Liberty	47,502	1,241	1,165	113	50,667	208
Live Oak	40,290	501	3,726	198	25,277	179
Matagorda	75,706	214	1,283	974	13,771	836
McMullen	36,600	41	69	5	1,037	7
Montgomery	37,599	2,874	2,105	93	61,744	338
Nueces	21,516	161	2,583	576	60,791	2,732
Orange	9,154	105	1,114	122	12,730	35
Refugio	39,874	65	893	3,223	4,134	146
San Patricio	36,666	86	1,483	332	50,203	161
Victoria	69,256	620	2,924	2,406	49,598	11,775
Walker	37,987	1,272	4,558	112	46,694	521
Waller	46,864	1,397	2,059	589	34,072	1,161
Wharton	88,655	1,733	2,357	1,067	69,349	2,222
Willacy	18,533	802	1,255	173	86,107	176

*U.S. Census of Agriculture, 1964

in the production of particular animals. *Five counties in the Coastal Zone are among the top ten in beef cattle production.* These counties include Brazoria (1), Harris (3), Wharton (6), Colorado (7), Austin (8). *Harris County also ranks second in the State in the production of dairy cattle.* Lavaca County ranks seventh in the production of swine and tenth in the production of turkeys, while DeWitt County ranks seventh in the turkey production. The characteristics of animal waste are presented in Table 21. The information in this table show that for beef cattle, *each animal produces 60 pounds of manure per day and each animal produces wastes which have the same strength of the waste produced by 3.5 humans based on the total pounds of Biochemical Oxygen Demand (BOD) produced.* The potential for pollution of surface and ground waters as the result of runoff from rainfall from those areas where animals have grown in high concentration is quite evident.

Many of these animals are raised in *feed lots*. A total number of 147 feed lot sites have been reported to be located in 28 of the 36 counties which are included in the Coastal Zone. The operating feed lots number 40 and are located in 14 counties. The reported number of sites which have been permanently closed is 45. This inventory of feed lots was made available by the personnel of the Texas Water Quality Board. Data for the Coastal Zone are summarized in Table 22 and Figure 9.

The State of Texas ranks second in the United States in the number of cattle marketed from feed lots. In 1968, 1594 cattle feed lots marketed 1,970,000 cattle. However, 1,858,000 cattle were marketed from 294 feed lots which had a capacity of over 1000 head of cattle.

The effective handling, treatment and disposal of these concentrated wastes must be included in any animal waste management program. The disposal methods represent additional costs, therefore, a wide variety of systems are employed. *The degree of treatment ranges from almost no treatment to extensive waste processing.*

Pesticides

Pesticides for the control of insects which damage crops and undesirable weeds enter the surface water during periods of runoff of storm water and from agricultural lands. The pesticides are transported by the streams and rivers to the bays and estuaries in the Coastal Zone. *Many of these organic compounds are not readily assimilated in the aquatic system and persist for long periods of time.* The results of a survey conducted by the Texas Water Development Board and the U.S. Geological Survey are presented in Tables 23 and 24. The data in these tables indicate that the pesticides which are commonly found in water samples include DDD, DDE, and DDT. The pesticides were found in the waters of four of the estuaries in which the survey was conducted. *It is interesting to note that in some of the sediment samples these insecticides were detected although no pesticides were present in the overlying water at the*

TABLE 21

CHARACTERISTICS OF ANIMAL WASTES*

	Beef Cattle	Dairy Cattle	Poultry	Swine	Sheep
Animal Weight (lb)	950	1400	5	200	100
Manure Produced (lb/day)	60.0	80.6	0.4	17.4	7.2
Dry Solids (lb/day)	10.0	10.0	0.1	0.9	1.7
BOD (lb/animal/day)	1.0	1.0	0.02	0.3	-----
Total Nitrogen (lb/animal/day)	0.3	0.4	0.003	0.05	-----
Population Equivalent**	3.5	------	-----	0.90	0.31

*Livestock Industries in Texas as Related to Water Quality, Preliminary Report, Texas Water Quality Board, June, 1970.

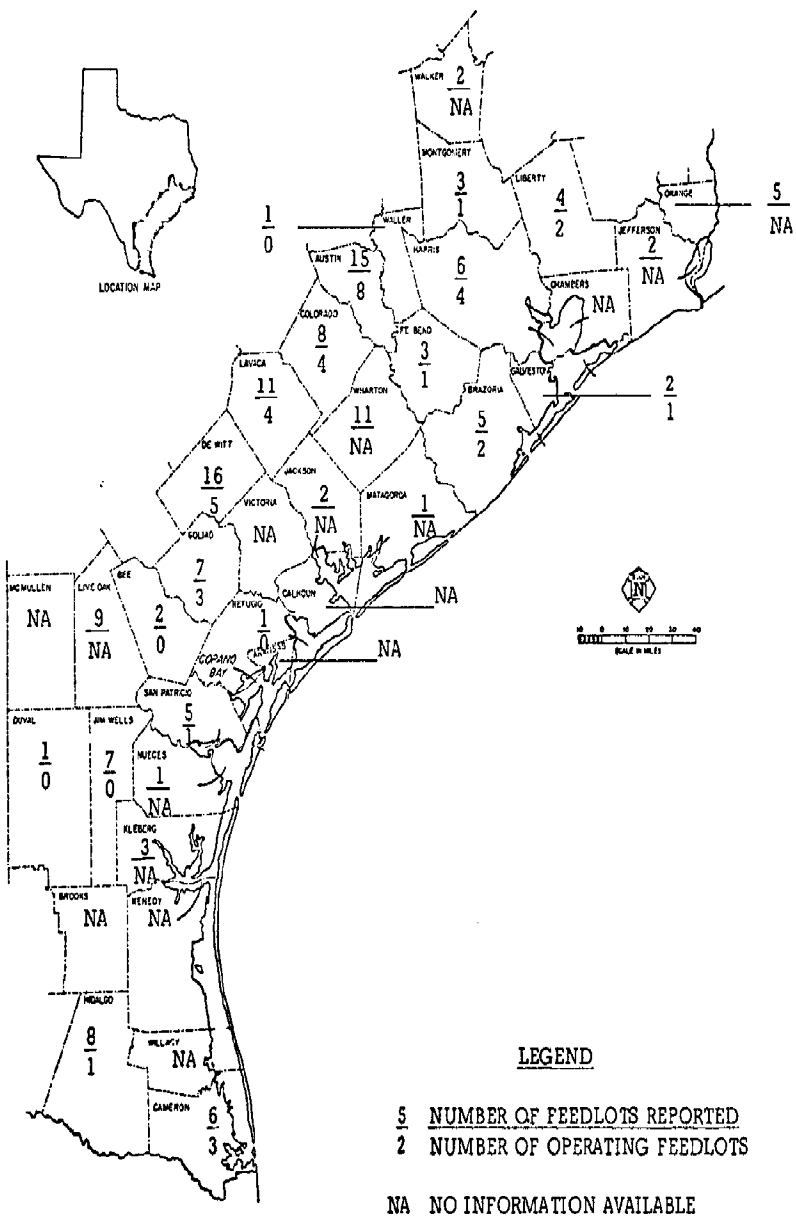
**Population Equivalent is the number of humans required to produce the same amount of BOD produced by one animal. These numbers are based on the contribution to the BOD of municipal wastewater attirbutable to the organic material in human excrement.

TABLE 22

FEEDLOTS*

	No. of Reported Sites	No. of Operating Sites	No. of Closed Sites	No Information
Aransas		No information available		
Austin	15	8	6	1
Bee	2	NA	2	NA
Brazoria	5	2	2	1
Brooks		No information available		
Calhoun		No information available		
Cameron	6	3	3	NA
Chambers		No information available		
Colorado	8	4	NA	4
DeWitt	16	5	NA	11
Duval	1	NA	1	NA
Fort Bend	3	1	2	NA
Galveston	2	1	1	NA
Goliad	7	3	NA	4
Harris	6	4	2	NA
Hidalgo	8	1	4	3
Jackson	2	NA	NA	2
Jefferson	2	NA	NA	2
Jim Wells	7	NA	7	NA
Kenedy		No information available		
Kleberg	3	NA	1	2
Lavaca	11	4	NA	7
Liberty	4	2	2	NA
Live Oak	9	NA	7	2
Matagorda	1	NA	NA	1
McMullen		No information available		
Montgomery	3	1	2	NA
Nueces	1	NA	NA	1
Orange	5	NA	NA	5
Refugio	1	NA	1	NA
San Patricio	5	1	1	3
Victoria		No information available		
Walker	2	NA	NA	2
Waller	1	NA	1	NA
Wharton	11	NA	NA	11
Willacy		No information available		

*Texas Water Quality Board (1970)
NA - No Information Available



LEGEND

5 NUMBER OF FEEDLOTS REPORTED
2 NUMBER OF OPERATING FEEDLOTS

NA NO INFORMATION AVAILABLE

FEEDLOTS (1970)

FIGURE 9

TABLE 23

Pesticides*

<u>Insecticides</u> A-DDD
B-DDE
C-DDT
D-Dieldrin

Estuary	Water A	Water B	Water C	Water D	Insecticide** Total (PPB)	Sediment A	Sediment B	Sediment C	Sediment D	Total (PPB)
Arroyo Colorado	x	x	-	-	0.05	N	N	N	N	
Arroyo Colorado Cutoff	-	-	-	-	----	x	x	-	x	3.21
Arroyo Colorado (Laguna Madre)	-	-	-	-	----	-	-	-	-	-----
Lavaca-Tres Palacios	-	-	x	-	0.01	x	x	x	-	22.80
Lavaca-Tres Palacios (Tres Palacios Bay)	-	-	-	-	----	x	x	-	x	3.17
Lavaca-Tres Palacios (Texas Intercoastal Waterway)	x	x	x	-	0.69	N	N	N	N	
Lavaca-Tres Palacios (Palacios Bay)	-	x	-	-	0.01	x	x	x	x	100.20
Lavaca-Tres Palacios (Lavaca Bay)	x	x	x	-	1.02	N	N	N	N	
Lavaca-Tress Palacios (Lavaca River)	-	-	-	-	----	x	x	x	x	8.16

*Texas Water Development Board (1970)
**(x) indicates compound is present in the sample
(-) indicates compound is not present in the sample
(N) indicates no sample available

TABLE 23 - Con'd.

Estuary	Water A	Water B	Water C	Water D	Insecticide** Total (PPB)	Sediment A	Sediment B	Sediment C	Sediment D	Total (PPB)
Guadalupe (San Antonio Bay)	-	-	x	-	0.02	x	x	x	x	3.64
Guadalupe (Guadalupe Bay)	-	-	x	-	0.61	x	x	x	x	9.14
Guadalupe (Guadalupe Estuary)	-	-	x	-	0.01	x	x	-	-	4.30
Guadalupe Guadalupe River	-	-	x	-	0.02	x	x	-	-	4.00
Colorado River	-	-	-	-	----	x	x	x	-	24.70
East Matagorda (Matagorda Bay)	-	-	-	-	----	x	x	x	-	2.83
Sabine-Neches	-	-	-	-	----	x	x	-	-	1.40
Laguna Madre (Baffin Bay)	-	-	x	-	0.01	x	x	-	-	2.50
Nueces Bay	-	-	-	-	----	N	N	N	N	
Nueces Estuary	-	-	-	-	----	N	N	N	N	
Mission-Aransas	-	-	-	-	----	N	N	N	N	

*Texas Water Development Board (1970)
**(x) indicates compound is present in the sample
(-) indicates compound is not present in the sample
(N) indicates no sample available

TABLE 24

Pesticides*

Herbicides A-2,4-D
B-Silvex
C-2,4,5,-T

Estuary	Herbicides** Water A	B	C	Total (PPB)	Sediment A	B	C	Total (PPB)
Arroyo Colorado	-	-	-	----	N	N	N	
Arroyo Colorado Cutoff	-	-	-	----	-	-	-	----
Arroyo Colorado (Laguna Madre)	-	-	x	0.01	N	N	N	
Lavaca-Tres Palacios	x	-	x	0.04	N	N	N	
Lavaca-Tres Palacios (Tres Palacios Bay)	x	-	x	0.22	N	N	N	
Lavaca-Tres Palacios (Texas Intercoastal Waterway)	-	-	-	----	N	N	N	
Lavaca-Tres Palacios (Palacios Bay)	x	-	x	0.27	N	N	N	
Lavaca-Tres Palacios (Lavaca Bay)	x	-	x	0.18	N	N	N	
Lavaca-Tres Palacios (Lavaca River)	-	-	-	----	N	N	N	

*Texas Water Development Board (1970)
**(x) indicates compound is present in the sample
(-) indicates compound is not present in the sample
(N) indicates no sample available

TABLE 24 - Con'd.

	Herbicide**							
	Water			Total	Sediment			Total
Estuary	A	B	C	(PPB)	A	B	C	(PPB)
Guadalupe (San Antonio Bay)	x	-	x	0.17	N	N	N	
Guadalupe (Guadalupe Bay)	x	-	x	0.27	N	N	N	
Guadalupe (Guadalupe Estuary)	-	-	-	----	N	N	N	
Guadalupe (Guadalupe River)	-	-	-	----	N	N	N	
Colorado River	x	-	x	0.07	N	N	N	
East Matagorda (Matagorda Bay)	x	-	x	0.08	N	N	N	
Sabine-Neches	-	-	x	0.02	N	N	N	
Laguna Madre (Baffin Bay)	-	-	x	0.02	N	N	N	
Nueces Bay	-	-	-	----	N	N	N	
Nueces Estuary	N	N	N		N	N	N	
Mission-Aransas	-	-	x	0.13	N	N	N	

*Texas Water Development Board (1970)
**(x) indicates compound is present in the sample
(-) indicates compound is not present in the sample
(N) indicates no sample available

time of sampling. A typical example is the Arroyo-Colorado Estuary at the Cutoff. The insecticides detected in the sediments included DDD, DDE, and Dieldrin. These data also indicate that insecticides *can be concentrated in the sediments of an estuary and bay*. This fact is pointed out by comparing the concentrations of the insecticides in the overlying water with that detected in the sediment. The concentration of insecticides in the water in the estuaries range between 0.01 and 1.02 parts per billion (ppb); however, the concentration of insecticides detected in the sediments range from 1.40 to 100.2 ppb. In fact, the lowest concentration of insecticides in the water was detected in the water sample taken at the location in Palacious Bay in which the sediment concentration was in excess of 100 ppb. This concentration of insecticides by the sediments *can be attributed in part* to the clay particles on which the insecticide is adsorbed which are flushed into the bays. Plankton which concentrate the insecticides upon dying will fall to the bottom of the bay or may be consumed by predators which in turn concentrate the compound. Insecticides are also removed from the water and become concentrated in the food chain. Relatively high concentrations have been reported in plankton and fish harvested from the bays in the Coastal Zone.

Samples of water from the various bays and estuaries were also analyzed for herbicides. The herbicides detected in the water samples included 2, 4-D, and 2, 4, 5, -T. The herbicides concentration ranged from 0.01 ppb to a maximum of 0.27 ppb. Only one sample of sediment was analyzed for herbicides; therefore, no information is available which would indicate the ability of the herbicides to persist in the environment for sufficiently long periods of time and become concentrated in the sediments.

Radioactive Substances

The release of radioactive materials into the environment can be another source of environmental pollution. There are 376 licensees for use of radioactive materials in the Coastal Zone. This number represents 33 percent of the licensees in the State of Texas. The licensees in the Coastal Zone are found in 17 counties. The location of the licensees for use of radioactive materials is presented in Table 25. This information was made available by the Occupational Health Division of the Texas Department of Health who monitor all possible sources of radiation pollution and regulate the use of radiation.

The majority of the radioactive material in the Coastal Zone is used in hospitals or in the offices of doctors and radiologists, and by well loggers. The radioactive material is used in such a way that there is little or no chance of release of this material to the environment. The only radioactive regulator located in the Coastal Zone is in the N. S. Savanah when this vessel is in port. The N. S. Savanah does not discharge any radioactive waste into the bays in the Coastal Zone. There are no radioactive dumps reported in the Coastal Zone. This data indicates that there are no present problems with releases of radiation into the environment.

TABLE 25

RADIOACTIVE SOURCES*

County	Number of Licenses For Radioactive Material
Aransas	1
Austin	3
Brazoria	10
Calhoun	2
Cameron	7
Colorado	1
DeWitt	7
Fort Bend	1
Galveston	24
Harris	223
Hidalgo	10
Jefferson	38
Matagorda	4
Nueces	28
Orange	8
Victoria	6
Walker	3

*Texas State Department of Health (1970)

LIMITATIONS OF INVENTORY

This inventory of waste sources is useful in *pointing to sources* of potential pollution; however, it *does not in itself provide any information regarding the collective effects of these discharges and emissions on the environment of the Coastal Zone.* The available data in many instances is incomplete and additional information is necessary in order to complete the inventory of waste sources in the Coastal Zone and to be able to evaluate the effects of these waste discharges on the environment.

Coordination of data collection, storage and management is essential. The result of this study indicates that a number of State agencies collect and store similar data to be used for different purposes. Many of the agencies *do not* upgrade their inventory of data as frequently as other agencies; therefore, different conclusions are drawn after reviewing what many people consider is the same information. Much of the available information is several years old and *does not* reflect any improvement in operation of the treatment or disposal facility which may have been completed since the data were collected.

Data which are necessary to complete the overall inventory of water carried pollutants include monthly information regarding the quality and flow of all municipal and industrial discharges. The *self-reporting system* of obtaining effluent quality and quantity information could provide the necessary information to maintain an accurate and current inventory of wastewater discharges. However, *the self-reporting system will be only of limited value if the municipal and industrial personnel can be convinced that they are not in jeopardy of retroactive penalties for not complying with the effluent standards.* This does not mean that the penalty for non-compliance would be eliminated. However, *some statute of limitation* should be established during which time the municipality or industry is subject to the penalty for non-compliance.

The quality of the receiving streams is necessary in order to effectively evaluate the effects of municipal and industrial discharges on the water quality. A system of data collection to provide this information would be extremely costly.

Presently water quality data are collected by the staff of the *Texas Water Quality Board* and of the *Texas Water Development Board* in cooperation with the personnel of the *United States Geological Survey. The inventory of water quality is not complete.* Continuous monitoring will be necessary to evaluate any improvement in water quality resulting from more effective wastewater treatment.

The cost of collecting this water quality information could be *markedly reduced* if the data were gathered by the industrial and municipal personnel who monitor the quality of their respective effluents. In other words, by tying the water quality information with the effluent quality data on a self-report system the cost of collecting the water quality information can be markedly reduced.

The quality of the surface water in the Coastal Zone was not a part of this inventory due to time and information-availability constraints; however, this information is essential to any water pollution control and water quality management programs. The effect of discharges from power stations which would increase the temperature of the receiving stream must also be included in these programs. Information of the quantity of water returned to the surface waters and the temperature of these returned flows are being collected by another task group and is not in this particular inventory.

The concentration of *heavy metals* in industrial and municipal discharges is also not routinely determined. The concentration of *coliform organisms* or other fecal organisms or viruses in municipal wastewaters and any sanitary waste from industrial plants should also be available. This information will provide a means of evaluating the treatment efficiency of the plant when considered in connection with the other effluent quality data.

Information relating to the *number of septic tanks* and absorption fields in the Coastal Zone is very sparse. The proximity of the ground water table to the surface of the ground on the Coastal Zone makes it imperative that the number of septic tanks be determined and that the quality of the ground water in the vicinity of the septic tank system be evaluated in order to determine the effect of the septic tank discharges on the water quality. It is especially important that those areas in the Coastal Zone which have high population densities and where septic tanks are used be identified and steps taken to eliminate septic tanks in those areas.

The *infiltration of storm water* during periods of heavy rainfall can markedly increase the quantity of wastewater which must be treated at the municipal treatment plant. The quantity of infiltration into the municipal collection system should be determined and proper steps be taken to *minimize infiltration* by proper water proofing of the joints in the collection system.

The *quality characteristics of storm waters* which flush a wide assortment of materials from rooftops, streets, industrial plant sites, agricultural lands, lawns and other surfaces must be determined in order to completely develop an effective inventory of pollution sources.

The effects of *drainage from open refuse dumps* which can contribute to the pollution load of streams should be evaluated. The extent of this pollution is dependent on the quantity and quality of flow in the stream as well as in the quantity of runoff from the dump. The effect of leachate for dumps on the quality of water in the ground water table in the Coastal Zone should also be evaluated.

Data which relate to the *direct contribution made by the runoff or percolation from feedlots* to the pollution of surface and ground water in the Coastal Zone are not complete at this time. The method of waste disposal and the quality of effluents from the operating feed lots should be determined. The staff of the Texas Water Quality Board are attempting to compile information regarding the operating feed lots and their effect on water sources and land.

The solid waste information available for the Coastal Zone is incomplete. The rate of refuse production for the counties in the Coastal Zone are estimates based on an estimate of the refuse collected and disposed of in municipal, private, and county facilities since very few municipalities actually weigh the collected refuse. Therefore, in order to determine the actual amount of refuse produced on a per capita basis it is essential that the weights of refuse collected be recorded and reliable estimates of the population served be developed. In many of the counties covered in this study, the population served within a county exceeded the population estimated by the 1970 Census. The quantity of refuse generated by those people who are not serviced by a municipal or private collection system must also be determined.

The number of *abandoned vehicles* and quantity of bulk wastes must be determined for the various counties in the Coastal Zone. Information relating to the quantity of *water treatment and waste treatment plant sludges* produced in the Coastal Zone as well as the method of disposal of these sludges must be included in any inventory of solid wastes.

There is almost no information available which relates to the characteristics and quantity of *industrial solid waste* generated in the Coastal Zone. The characteristics of the industrial solid waste are as varied as there are industries since each particular type of industry generates a specific type of industrial solid waste. Sludges and other residue formed by industrial activity must also be included in this inventory of industrial solid wastes. The staff of the Texas Water Quality Board has embarked on a program to develop quantitative and qualitative data for industrial solid wastes.

The information dealing with the solid waste disposal practices in the Coastal Zone is based on the 1968 survey. More current surveys must be completed in order to determine what effect the curtailment of open burning by legislation has on converting the open dumps to sanitary landfills. In many areas the "Rest Areas" provided along the highways by the Texas Highway Department have become the *dumping grounds for household refuse.* It is essential that all open dumps be converted to sanitary landfills, in order to reduce potential water and air pollution which are generally associated with open dumps. Conversion of the open dumps to sanitary landfills will also improve the overall health of the community and environment by eliminating breeding places for rats, flies, and mosquitoes. The quantity of manure generated at feedlots and methods of manure disposal must also be considered in any overall inventory of solid wastes.

The sources of *industrial air pollution* and the Coastal Zone have been compiled and the characteristics of the emissions summarized by the Texas Air Pollution Control Board. Very little information is available which indicate the effects of these atmospheric discharges on the overall quality of the air and Coastal Zone. The surveillance of the individual discharges of industrial air pollutants must be monitored in order to maintain a current inventory of quantity and quality of emissions into the atmosphere. The characteristics of the industrial emissions as well as the quality of the ambient air can be reported on a regular basis. A self-reporting system similar to that proposed for monitoring wastewater discharges should be developed for air quality monitoring.

The contribution to the emissions to the atmosphere by *automobiles* also contribute to the overall quality of the air in the Coastal Zone. Federal legislation which requires air pollution control devices on all new cars will significantly reduce the quantity of these emissions. The contribution to the overall air pollution in the Coastal Zone caused by open burning of refuse at open dumps must also be included. However, as the open dumps are converted to sanitary landfills this source of air pollution will be eliminated. An inventory of emissions into the atmosphere from other activities such as cotton ginning, grain, drying and storage must also be included in the inventory of air pollution.

An overall inventory of the quantity of *organic pesticides and heavy metals* which enter the surface waters in the Coastal Zone should be completed. The heavy metals and pesticides accumulate in the aquatic food chain. There is considerable evidence, based upon Parks and Wildlife data, that these materials build up in the sediments, and become concentrated there. Therefore, a routine program is needed to determine the concentration of these materials in both the tissues of the organisms forming the food chain and in the underlying sediments. This information could then be used to assess the impact of these materials on the entire aquatic community.

APPLICATIONS OF INVENTORY

A complete inventory of waste sources in the Coastal Zone of Texas is essential to the development and planning of a complete program of environmental quality management. *The interaction among the air, land, and water environments make it necessary that all liquid, solid, and gaseous emissions into the environment must be included in any plan.* The completed inventory can be used for a multitude of planning programs.

On a local level, the officials can have a realistic assessment of the emissions into the environment and the overall effects of these discharges on the environment. In many cases, the resources of a particular municipality or county may not be sufficient to cope with the control of pollution. However, if the county was incorporated into some type of regional planning program or into some area council of governments, financial resources and technical competence can be made available to even the smallest community or the least densely populated county. There are five area councils in the Coastal Zone at the present time. The counties which make up the individual planning groups are shown in Figure 10. These groups include all but six of the counties. A complete inventory of waste sources for the counties in a particular planning council would also assist these groups in developing an effective plan of action for managing the quality of the environment. This information can be used to inform the public of the overall environmental quality. In this way, the public can decide on the steps that must be taken to remedy the situation and improve the environmental quality. This information can also be used as a basis on which to *decide what degree of industrial development might be permitted to take place in a given area.* On the other hand, industry can also take advantage of such an inventory in evaluating the resources of a particular county in the Coastal Zone as well as the quantity of emissions and discharges already present near the proposed plan site.

State agencies which have specific responsibilities for various aspects of environmental quality maintenance can also benefit from a complete inventory of waste sources. Those agencies which are responsible primarily for the enforcement of pollution control legislation and maintenance of environmental quality can use the inventory to quantitatively identify those areas which the effluents must be cleaned up to a greater extent in order to maintain or improve the quality of the air and water resources. By continuous updating of the inventory, these agencies can also have available the changes in environmental quality resulting from enforcement of pollution control legislation. Those agencies responsible for the planning of the resources of the Coastal Zone can also benefit from a waste inventory. This inventory would immediately provide an indication of the pollutional effects or load on the environment resulting from

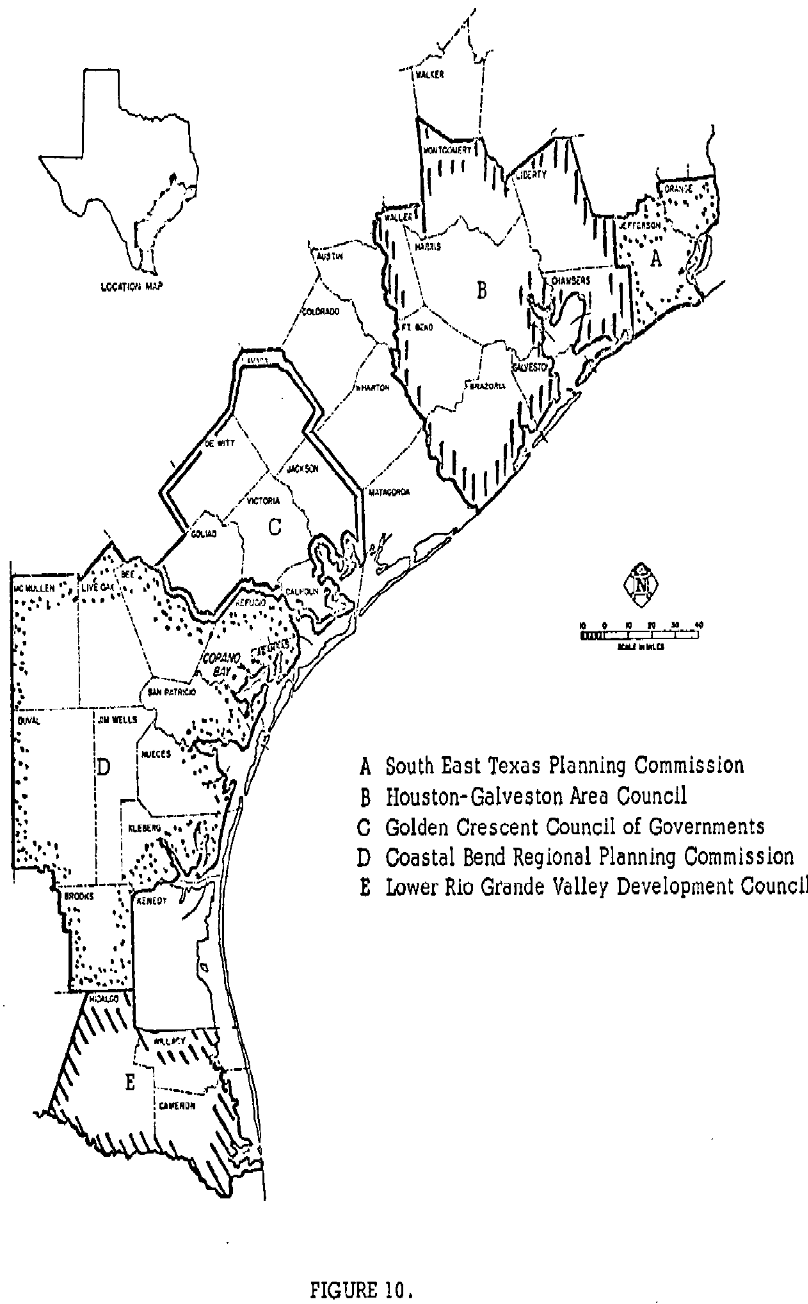


FIGURE 10.
AREAL PLANNING COUNCILS

development of the resources of the region. *The consequences of developing other resources in the Coastal Zone can also be projected on the basis of environmental effects of past development.*

An inventory of all of the pollution sources should be developed not only for the Coastal Zone, *but for the entire state. This state-wide inventory is especially important when it comes to developing a water resources management program.* All of the major Texas rivers flow from the inland portion of the state through the Coastal Zone and into the Coastal bays. Therefore, persistant organic and inorganic constituents of wastewaters can be transported great distances in our streams and dumped into the estuary and bay streams. The accumulation of toxic materials in the food chain of the aquatic organisms of the bays and Gulf waters can reduce the value of the commercial fisheries in the Coastal Zone. The quality of the water in the bays and estuaries of the Coastal Zone can be markedly affected, not only by the industrial and municipal discharges of wastewater, but also by the regulations of the flow of fresh water carried by the rivers which flow from the inland portion of the state into the Coastal area. As more stringent effluent standards are required for industrial and municipal wastewater discharges, the *complete reuse of water* by industries and municipalities would further reduce the quantity of fresh water which is returned to the estuary and bay system.

The influence of the *reduced freshwater flows* caused by impoundment of streams *coupled with increased reuse of water* must be considered in any overall water resources management plan.

Atmospheric emissions effect the immediate area into which they are released. However, these materials may be carried by the wind for great distances and may in fact have a detrimental effect on the quality of the air in counties in which no industrial emissions are located. Therefore it is essential that an inventory of the atmospheric emissions for each area of the state be available and that a current inventory of the quality of the air in various counties also be maintained.

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A WATER INVENTORY OF THE TEXAS COASTAL ZONE

Prepared by

Texas Water Development Board

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for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

CONTENTS

A WATER INVENTORY OF

THE TEXAS COASTAL ZONE

I. *INTRODUCTION*

The present demand for water, availability of water supplies, and future water-supply potential and water-use conflicts within the Texas coastal zone are perhaps as diverse as all of the principal coastal areas of the U. S. compared with one another.

The *large industrial and agricultural sectors* of the dynamic economy of the coastal zone require and use vast quantities of water. *Large population centers* which have developed, principally in the heavily industrialized areas such as Orange-Beaumont-Port Arthur, Houston-Baytown, and Corpus Christi have also created large local demands for fresh water. Collectively, municipalities, industry, mining, agriculture, and maintenance of adequate environmental conditions for continuing productivity of the estuaries make the coastal zone the most "water-demanding" area of Texas. Through the use of saline water by industry, where feasible, avaiable water supplies have generally been adequate to meet the progressively increasing demands of the region, although heavy *overdraft* of ground water aquifers in localized areas has substantially contributed to an increasingly menacing pair of problems - *land subsidence and saline-water intrusion*. However, even without considering the fresh water needs of the estuaries, some areas of the coastal zone are fast approaching, or have already reached, critical shortages of fresh water.

The distribution of existing and projected water supplies and demands within the 400 mile-long coastal zone presents a tremendous challenge to long-range water resource planning. Alternative methods, and combinations thereof, for meeting future shortages which have received intensive study include, among others, *conveyance* of water from surplus areas in East Texas, *desalting*, and *wastewater renovation* and *reuse*. Owing to the relatively high cost of desalting and wastewater renovation, particularly as such relate to agricultural supplies, *redistribution by conventional methods is presently considered the most feasible solution*. Desalting does offer considerable potential for meeting both interim and long-range municipal and industrial water supply problems in various parts of the coastal zone, however. Likewise, wastewater renovation *is technically feasible* and offers promise as a supplemental source of industrial, agricultural, and possibly even municipal supplies in some areas. The *NUPLEX concept* has also created considerable interest as it would appear to be particularly applicable to coastal areas such as the Texas coastal zone.

This concept, presently under intensive investigation by Texas A&M University, involves the use of nuclear power for large scale desalting plants, in the *100 mgd-plus* capacity range, coupled with highly advanced agricultural techniques which could potentially result in production of specialty crops, under rigidly controlled environmental conditions, *using only a fraction* of the water required by conventional irrigation practices. Such concepts will require many more years of research and demonstration, however, before inclusion in long-range water supply plans for the coastal zone which must be implemented to meet the needs of critical water short areas in time to avoid economic detriment. Detailed feasibility studies, design, state and/or federal authorization, and construction of water supply and conveyance projects require many years for completion.

The main thrust of comprehensive long-range planning for water development and management in Texas has *thus been oriented toward equitable distribution of all available supplies,* implementation of *economically feasible* projects in time to meet projected shortages, and resolution of use-conflicts so that increasing development and upstream use of fresh water supplies *will have the least possible adverse effect* upon Texas' coastal zone.

Present demands for water, sources of supply, principal water users, and projected fresh water demands within the coastal zone are given in Table 1. Figure 1 illustrates the location of existing, proposed, and alternative major reservoirs, as set forth in the *Texas Water Plan,* for meeting fresh water demands in the coastal zone to the year 2020. Figures 2 and 3 illustrate the distribution of major and minor ground water aquifers in Texas as they relate to the coastal zone. Figure 5 illustrates the configuration of the proposed Texas Water System to the year 2020, including various alternative water conveyance routes for supplying projected water deficient areas of the coastal zone.

II. WATER SUPPLIES IN THE COASTAL ZONE, PRESENT AND FUTURE

Southeast Texas Region

The Southeast Texas Region, encompassing Orange, Jefferson, and Chambers Counties, includes the *highly industrialized* Orange, Beaumont, and Port Arthur urban complex as well as *vast areas of irrigated agriculture, principally rice.* Petroleum refining, manufacturing of chemicals and allied products, rubber and plastics, paper and allied products, sulphur mining, and electric power generation require the largest quantities of water used in the region. Most of the area is supplied by water diverted from the *Sabine and Neches Rivers* and their tributaries, although many refineries and chemical plants, as well as power generating plants, *utilize saline water from the Sabine Lake estuarine complex.* The *Gulf Coast aquifer* supplies small amounts of ground water for municipal, domestic, and agricultural use in the region, although practically none for industrial use.

*TABLE 1. REPORTED MUNICIPAL AND INDUSTRIAL WATER USE WITHIN THE TEXAS COASTAL ZONE, 1968.**

(Acre-Feet)

Region and County	Surface Water Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Water Industrial
Southeast Texas					
Orange	-	28,525	4,753	13,777	1,058,562
Jefferson	28,284	163,548	26	7,798	850,705
Total	28,284	192,073	4,779	21,575	1,909,267
Gulf Coast					
Chambers	-	7,718	538	2,905	-
Liberty	-	5,289	1,962	33	-
Walker	-	-	3,298	-	-
Montgomery	-	-	2,977	1,336	-
Harris	33,315	154,322	195,005	163,364	650,834
Galveston	-	47,017	22,881	9,020	432,516
Brazoria	-	159,034	2,368	10,139	2,678,995
Ft. Bend	-	522,227	3,437	14,511	-
Waller	-	-	1,119	3,192	-
Austin	-	-	626	18	-
Colorado	-	1,667	1,316	3,739	-
Wharton	-	6,068	2,350	6,802	-
Matagorda	-	5,050	2,320	4,740	-
Total	33,315	908,392	240,197	219,799	3,762,345
Golden Crescent					
Lavaca	-	-	1,370	123	-
Jackson	-	-	1,209	268	-
Calhoun	-	15,235	1,629	2,601	18,855
Victoria	-	248,764	5,944	4,530	-
De Witt	-	-	1,121	146	-
Goliad	-	-	259	2	-
Total	-	263,999	11,532	7,670	18,855
Coastal Bend					
Refugio	-	-	720	487	4
Bee	-	-	2,240	619	28
San Patricio	2,813	7,159	1,111	169	-
Live Oak	286	-	144	297	-
Nueces	28,438	33,773	233	1,641	269,135
McMullen	-	-	44	358	-
Jim Wells	1,940	-	796	1,202	-
Duval	-	-	878	1,544	-
Kleberg	-	-	4,355	3,514	78
Brooks	-	-	831	424	90
Kenedy	-	-	7	12	-
Total	33,477	40,932	11,359	10,267	269,335

**See footnote at end of table.*

Table 1 (continued)

(Acre-Feet)

Region and County	Surface Water Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Water Industrial
Lower Rio Grande Valley					
Willacy	4,311	-	83	2	-
Hidalgo	31,672	5,101	3,663	948	37
Cameron	30,032	3,818	1,501	72	238,800
Total	66,015	8,919	5,247	1,022	238,837
Coastal Zone Total	161,091	1,414,315	273,114	260,333	6,198,639

Figures are based on annual inventory by Texas Water Development Board of all municipalities of 5,000 population or more and industries using a minimum of 100,000 gallons per day of water.

During calendar year 1968, demands for municipal use amounted to more than *33,000 acre-feet,* of which about 28,000 acre-feet was supplied by surface water. The demand for fresh water for industrial use in 1968 amounted to about *314,000 acre-feet,* while an additional *2,000,000 acre-feet* of saline water was utilized in industrial processes and as cooling water in steam-electric power generation. Most of the non-saline surface water presently used for municipal, industrial, and irrigation purposes in the Southeast Texas Region is obtained from the Sabine River Authority of Texas' diversion system and the Lower Neches Valley Authority canal system. Some irrigation water is supplied from the Trinity River through the existing facilities of the Devers Canal Company and the Chambers-Liberty County Navigation District.

The use of water for irrigation in the region historically has been *almost entirely for the production of rice.* The combination of the soil types, level terrain, and the high rainfall rate make this area well suited for rice production. According to the 1969 irrigation inventory conducted by the Soil Conservation Service, *126,585 acres of rice* were grown in the region that year, mostly in Chambers and Jefferson Counties. The gross water requirement for this production reportedly was 315,064 acre-feet of surface water and 1,118 acre-feet of ground water. Since ground water in most of the region is generally saline, very little is presently being used for irrigation and only minor use of ground water for irrigation is anticipated in the future.

Through a Compact with the State of Louisiana, ratified by the 53rd Texas Legislature in 1953 and approved by the Louisiana Legislature and Congress in 1964, the waters of the Sabine River between the point where downstream flows first touch both State lines and Sabine Lake are equally divided between the two states. The average annual discharge of the Sabine River near Ruliff, about 23 river miles above the City of Orange, for the 44 year period 1924-1968 was 8,187 cfs (cubic feet per second) or *5,927,000 acre-feet per year.* There have of course been "drought" periods, when flows have been less than 200 cfs, as well as floods when maximum discharges have exceeded 120,000 cfs.

Toledo Bend Reservoir, constructed jointly by the States of Texas and Louisiana and closed in late 1966, now provides regulation of the flow of the Sabine River in the Southeast Texas Region. This giant reservoir, with a total capacity of more than *5 million acre-feet* of water is operated for hydroelectric power generation as well as providing a firm water supply for downstream demands.

The Neches River also furnishes large quantities of water for municipal, industrial, and agricultural uses in the region. The Lower Neches Valley Authority canal system diverts water primarily from the main stem Neches River, although some water is also obtained periodically from Pine Island Bayou - a principal tributary of the Neches in the Southeast Texas Region. The flow of the Angelina River, the major tributary of the Neches River, is now largely regulated by *Sam Rayburn Reservoir,* completed in 1965. This reservoir, with a total capacity of more than *5,600,000 acre-feet,* is presently operated for flood control and hydroelectric power generation, although more than 2,800,000 acre-feet of its capacity is presently allocated to conservation storage (while still operated for power generation). *B. A. Steinhagen Reservoir,* a 124,700 acre-foot capacity reservoir located just below the confluence of the Angelina and Neches Rivers, was completed in 1951 and also partly regulates the flow of the lower Neches River as well as providing municipal, industrial, and agricultural water supplies for the area.

Ground water of suitable quality for municipal, agricultural and certain industrial uses occurs in the Gulf Coast aquifer only in the northern part of the region, with the best quality water occurring in northern Orange County. The City of Orange obtains its water supply from the aquifer, as do several industrial plants in the region. Ground water pumpage has, however, contributed to the problem of land subsidence locally, particularly in Orange County.

The demand for municipal and industrial fresh water supplies in the Southeast Texas Region is projected to reach approximately *750,000 acre-feet annually by the year 1990 and about 1,667,000 acre-feet annually by the year 2020.*

Some increase in rice production is expected to develop in the region, although it will be limited by the competition for land due to increasing urbanization and industrialization. Improved rice varieties and farming techniques may, however, increase per acre yields without a significantly increasing water demand.

By 1990 the irrigation water requirements of the region are estimated to increase to approximately 533,500 acre-feet annually and by 2020, the demand is expected to reach *564,500 acre-feet annually.* Surface water will continue to supply most of the demand.

Existing and proposed reservoirs in the Sabine and Neches River Basins are expected to more than adequately supply projected demands in the region and will also create surplus supplies which will be available for use in other areas of the State. Under the Texas Water Plan, after all projected demands in the region are satisfied, a portion of these surplus surface water supplies would be diverted into the *Coastal Canal* of the proposed Texas Water System for conveyance to areas of projected shortages within the coastal zone. An alternative possibility set forth in the Plan would involve diversion of future surpluses developed in the Neches River Basin westward into the Trinity River Basin, thence southward into the San Jacinto River Basin to supply part of the Houston metropolitan area's projected future needs.

Although the Southeast Texas Region is endowed with abundant surface water resources, maintenance of the natural high quality of these resources through well planned and implemented water-quality problems identified in this paper must and are being corrected as much as possible. Full development of the surface water resources of the Sabine and Neches River Basins, essential to satisfy projected needs of this area and other regions of the coastal zone, must be accompanied by maximum waste-treatment efficiency and project operation criteria which will result in optimum beneficial use for the State.

Full development of these basins' resources will also require construction of salt water barriers on the lower reaches of the rivers to prevent upstream migration of saline water during periods of low flow. The consequences of possible alteration of the environments of these estuaries, and Sabine Lake, as a result of project development need thorough study. *Any potentially adverse affects, in terms of productivity of these areas, must be fully defined by rigorous benefit-cost analyses, including consideration of the future demands for fresh water in other parts of the coastal zone.*

Gulf Coast Region

The Gulf Coast Region, extending westward past the Colorado River and northward into the heavily pine-forested area of Walker County in the San Jacinto and lower Trinity River Basins, includes the vast Houston urban complex and is by far *the most diverse socio-economic area* of the Texas coastal zone.

Petroleum refining and related industries and production of chemicals and allied products, centered largely in the Houston-Baytown-Texas City industrial complex, are by far the largest water demanding industrial sectors in the region, followed by electric power generation (which largely uses saline water), production of paper and allied products, primary metals, and sulphur mining. In 1968, industrial demands for fresh water were reportedly approximately *1,188,000 acre-feet*, of which about 968,000 acre-feet was supplied by surface water resources and the remainder by ground water. An additional reported *3,762,000 acre-feet of saline water* was used, primarily in the production of chemicals and allied products, petroleum refining, primary metals (more than 2,985,000 acre-feet), and electric power generation (about 776,000 acre-feet). Much of this was used for cooling water, although it should be mentioned that a reported 2,678,456 acre-feet of the total saline water demand was by a single plant (Dow Chemical at Freeport) which extracted elemental bromine and magnesium from sea water. The facility for bromine extraction at this plant has subsequently been closed.

Municipalities and communities of the Gulf Coast Region reported use of *273,512 acre-feet* of fresh water in 1968. Of this total, approximately 240,000 acre-feet was supplied by ground water pumped from the Gulf Coast aquifer. The City of Houston reported use of 180,394 acre-feet of water in 1968, of which 147,079 acre-feet was ground water. The Cities of Houston, Baytown, Bellaire, Clear Lake City, Galena Park, Jacinto City, South Houston, and Pasadena collectively pumped approximately 170,500 acre-feet of ground water during 1968.

The region is currently producing over fifty percent of the rice produced in Texas. Rice is by far the major irrigated crop grown in the twelve county region, with lesser acreages of other irrigated crops, mainly cotton and grain sorghum, being grown primarily in the delta soils along the Colorado and Brazos Rivers. In 1969, according to the irrigation inventory conducted by the Soil Conservation Service, 394,156 acres were irrigated within the region using 1,215,943 acre-feet of water. Of this water demand, approximately 57 percent was from surface water sources, and the balance derived from ground water pumped from the Gulf Coast aquifer (Figure 4).

Municipal, industrial, and some agricultural fresh water supplies in the Gulf Coast Region are presently supplied primarily by Lake Houston, in the San Jacinto River Basin, and by ground water. Irrigation demands are also supplied by diversions from the Brazos and Colorado River Basins through canal systems owned and operated by the Brazos River Authority, Lower Colorado River Authority, and several privately-owned companies. Facilities are presently under construction to supply additional water to the Houston area with diversions from the lower Trinity River. Regulation for such diversions will be provided by recently-completed *Livingston Reservoir* on the main stem of the Trinity River. *Wallisville Reservoir,* presently under construction near the mouth of the Trinity River, will make additional supplies available when completed, as will *Conroe Reservoir* which is presently in preliminary stages of construction in the upper San Jacinto River Basin. Diversions from the Trinity River through the conveyance and storage facilities presently under construction to the Houston area are intended primarily to serve industrial plants along the Houston Ship Channel. This "transition" to a more evenly distributed combined ground- and surface-water supply will reduce present localized heavy overdraft on the Gulf Coast aquifer in this particular area.

The demand for fresh water for municipal and industrial use in the Gulf Coast Region of the Texas Coastal zone is projected to reach more than *2,000,000 acre-feet annually by 1990* and approximately *3,800,000 acre-feet annually by 2020.* Although urbanization and industrialization will compete strongly with agriculture for remaining land resources in the region, agricultural water demands are expected to increase to approximately *1,570,000 acre-feet annually by 1990* and about *1,803,000 acre-feet annually by the year 2020.*

Full development of the surface water resources of the San Jacinto River Basin, diversion from the Trinity River Basin (Livingston and Wallisville Reservoirs), and ground water in the Gulf Coast aquifer should be capable of supplying these projected demands to about the year 2000 or beyond, assuming that pumpage of ground water from the aquifer is properly managed and is held to the "safe yield" of the aquifer. *Additional supplies from other sources will be required to meet longer-range needs of the region, however.*

Provisions of the *Texas Water Plan* for satisfying these long-range requirements include *interbasin transfer* of projected surpluses in the Neches River Basin into the region and increased diversions from the Brazos River Basin. Alternatives for conveying surface water from the Neches River Basin to the region include (1) diversion directly into the proposed Coastal Canal of the Texas Water System, (2) enlargement and extension of the existing LNVA canal system into the area, and (3) routing through proposed Bedias Reservoir in the Trinity River Basin (and also utilizing the yield of this reservoir) and thence into the San Jacinto River Basin.

Major problems relating to water supply in the Gulf Coast Region include *water-quality management, land subsidence,* and *saline ground water intrusion* in the Gulf Coast aquifer. Fresh water inflow needs of the Galveston Bay System under alternative management plans for this important estuary are presently under intensive study. As inland fresh water supplies are progressively developed and used, fresh water inflows to Galveston Bay will be correspondingly diminished. Provisions of the Texas Water Plan include an allocated firm annual supply of fresh water from the proposed Coastal Canal. *Unless such a firm supply is available, and cost criteria and repayment procedures established as quickly as possible, the existing ecological structure of Galveston Bay will no doubt be altered as a result of reduced fresh water inflows.*

Land subsidence, resulting largely from localized intensive ground-water pumpage and also withdrawals of petroleum, natural gas and brine from hydrocarbon reservoirs, is already a very severe problem in the Gulf Coast Region. Areas along the Houston Ship Channel and in the Baytown vicinity are most critical. Heavy ground-water pumpage has caused *saline-water intrusion* in the Texas City and Baytown areas. Proper well spacing and *ground water management* is absolutely essential to minimize further land subsidence and to protect this valuable aquifer.

Golden Crescent Region

The Golden Crescent Region, which encompasses much of Lavaca River Basin and the lower part of the Guadalupe River Basin between the Colorado and San Antonio Rivers, is centered around the City of Victoria. The *economy of the area is based principally on agriculture* (largely cotton and rice) and livestock and poultry farming, although production of hydrocarbons, petroleum refining and related industries, production of primary metals, and manufacutring of chemicals and allied products contribute substantially to the economy and represent the major water users of the region.

During 1968, approximately *290,500 acre-feet* of water was used for industrial purposes in the region, of which about *283,000 acre-feet* was derived from surface water sources and the remainder from the Gulf Coast aquifer. A reported 18,855 acre-feet of this total was saline surface water. Approximately 177,000 acre-feet of the total industrial demand was cooling water used in the generation of electric power; thus, actual consumptive use for industrial purposes in the region is presently comparatively small.

Municipal water demands during 1968 amounted to only a reported *11,532 acre-feet*, virtually all of which was ground water pumped from the Gulf Coast aquifer. The City of Victoria was the largest municipal water user, reporting a total of 5,795 acre-feet of ground water used during 1968.

Irrigation in the Golden Crescent Region is primarily for the production of *rice*. Very little water is presently being used for production of other crops. In 1969, the demand for irrigation water totaled approximately 198,000 acre-feet. Ground water from the Gulf Coast aquifer presently supplies most of the agricultural requirements in Jackson, Lavaca, and Victoria Counties. Calhoun County is the major user of surface water. In 1969, about 37,000 acre-feet was diverted from the Guadalupe River to irrigation projects in Calhoun County through facilities owned and operated by the Guadalupe-Blanco River Authority. Small amounts of water are diverted from Garcitas Creek and the Lavaca River for agricultural use in western Jackson County.

Municipal and industrial fresh water demands of the Golden Crescent Region are projected to increase to about *300,000 acre-feet by 1990* and approximately *436,000 acre-feet annually by the year 2020*. Most of this projected increase is expected to occur in the Victoria area and in Calhoun County, where industrial water demands are expected to increase markedly. Irrigation is expected to expand in the region, particularly in view of the projected increase in demand for rice on the world market and the availability of suitable soils and yet undeveloped ground- and surface-water resources of the region. By 1990, irrigation water demands are estimated to increase to approximately *233,600 acre-feet annually*. *Competition for land by increased urban and industrial development is expected to keep irrigation at approximately this level through the year 2020*. Most of the increased irrigated acreage is projected to be supplied by ground water, although a significant increase in use of surface water for irrigation is also projected.

Although there are presently *no existing major reservoirs* in the region to meet these increased demands, the Gulf Coast aquifer is capable of supplying some additional water to partially meet future needs. Congress has authorized construction of Stage 1 of *Palmetto Bend Reservoir* (Navidad River arm) and land acquisition for Stage 2 (Lavaca River arm) of the reservoir. This reservoir, as presently designed, would have a conservation storage capacity of more than 230,000 acre-feet and a firm yield of approximately 105,000 acre-feet, which will provide additional municipal, industrial, and agricultural supplies for the region as well as adjacent areas of the coastal zone. In addition to Palmetto Bend Reservoir, *Garcitas Reservoir* is a potential reservoir in the Texas Water Plan which could provide additional fresh water supplies for the region if ultimately needed.

The major problems facing this area of the coastal zone are (1) *intrusion* of saline ground water if the Gulf Coast aquifer is improperly developed or overdeveloped, as well as potential land subsidence which commonly results from heavy overdraft of the Gulf Coast aquifer, and (2) impending *dimunition of inflows* to Matagorda and San Antonio Bays as a consequence of progressively increasing demands for water in the rapidly developing urban areas of the San Antonio, Guadalupe, and Lavaca River Basins. In order to avert an impending critical municipal water supply problem projected to develop in the San Antonio area about 1985-90, the Texas Water Plan proposed construction of *Cuero and Cibolo Reservoirs* in the Guadalupe and San Antonio Basins, respectively, to supplement ground water supplies now used. The heavily pumped Edwards aquifer presently furnishes a large part of the municipal, industrial, and agricultural water supplies in these basins, and also sustains the flow of the many important springs which feed streams of these basins. Provisions of the Plan also provide for construction of *Goliad and Confluence Reservoirs*, which would provide water supply and re-regulation, respectively, for the proposed Coastal Canal of the Texas Water System. *Reduced fresh water inflows as a result of upstream development would be offset by regulated releases of fresh water into San Antonio and Matagorda Bays from the Coastal Canal.*

Coastal Bend Region

The Coastal Bend Region, extending from the San Antonio River southward to the Lower Valley, *has both a highly diversified climate and economic base.* Surface water supplies available to the region are principally confined to the northern part of the region. Ground water of suitable quality for a municipal, agricultural, and most industrial uses is largely confined to northwestern corner of the region, where comparatively large quantities are pumped from the Carrizo-Wilcox aquifer largely for irrigation.

Industrial development and associated population centers are principally confined to the Corpus Christi-Kingsville area. Agriculture (cotton, grain sorghum, and vegetables), cattle ranching, and production of hydrocarbons constitute the basic economy of the region, although petroleum refining and related industries, manufacturing of chemicals and allied products, and primary metals industries contribute substantially to the economy and represent major industrial water users of the region. The principal industrialized areas and the largest demands for water are in Nueces and San Patricio Counties. Very little agricultural land is irrigated because of inadequate water supplies to support irrigation projects.

Reported industrial water demands within the region in 1968 totaled approximately *320,000 acre-feet,* of which a reported 269,335 acre-feet was saline water. A reported 184,575 acre-feet of this total saline water use was for cooling in the production of electrical power.

Ground water supplied slightly more than 10,000 acre-feet of the reported 51,200 acre-feet of fresh water utilized by industry in the region in 1968. Most of this was pumped from the Gulf Coast aquifer. Industrial surface water supplies, exclusive of saline water, are obtained primarily from the Nueces River Basin.

Municipal water demands in the region during 1968 reportedly amounted to about *45,000 acre-feet,* of which a reported 11,359 acre-feet was ground water obtained principally from the Gulf Coast aquifer. Corpus Christi, the largest city of the region, used a reported 29,627 acre-feet of water during 1968, all of which was supplied from *Lake Corpus Christi,* while Alice, also partly supplied by diversions from the Nueces River into *Lake Alice,* used approximately 2,000 acre-feet of water. Principal cities presently relying on ground water for municipal supplies include Beeville, Refugio, Sinton, and Kingsville. Both the quantity and quality of ground water in the Gulf Coast aquifer in the Coastal Bend Region vary widely, and in many areas the ground water is unsuitable or of marginal quality for municipal and many industrial uses. As an example, some of the supplies used from this aquifer are of inferior quality and exceed U. S. Public Health Service recommended drinking water standards.

During 1969, *20,941 acre-feet* of water was used for irrigation in the region, 16,851 acre-feet of which was ground water pumped primarily from the Gulf Coast aquifer.

Lake Corpus Christi, completed in 1934 and later enlarged in 1958, is located on the Nueces River above Corpus Christi and is the only existing major reservoir in the region. This reservoir, with a total capacity of about 308,000 acre-feet, was constructed by the City of Corpus Christi and provides municipal and industrial water supplies for Corpus Christi as well as Alice, Aransas Pass and Port Aransas, and cities and communities in San Patricio County. Supplies for Corpus Christi and adjacent areas are released from the reservoir and diverted from the Nueces River at Calallen 35 miles downstream. Distribution systems to serve Port Aransas and areas of San Patricio County have only recently been enlarged and extended. The yield of Lake Corpus Christi has generally been sufficient to meet the industrial and major municipal demands of the users holding existing permits for supplies from the reservoir. *The Coastal Bend Region, however, has great potential for economic development, including irrigated agriculture, industry, and expanded tourism and recreation, if additional water supplies could be made available to the area.* Some of the most fertile and potentially productive soils in Texas occur in the central part of the region which *could* support greatly expanded agricultural development *if* irrigation water was available.

Even without development of the vast irrigated agriculture potential of the area, however, parts of the Coastal Bend Region will become one of the more critical water-short areas of the State with normal projected economic growth. Municipal and industrial fresh water requirements of the region are projected to increase to approximately *266,200 acre-feet annually* by 1990 and about *526,500 acre-feet per year by the year 2020.* The surface water resources of the Nueces River Basin will support one additional major reservoir in the region. Two potential projects, *R&M and Choke Canyon Reservoirs,* have received extensive study, and are included in the Texas Water Plan as alternative projects to be decided upon by local interests. Based on recent local decisions, the U. S. Bureau of Reclamation is completing detailed feasibility studies of the R&M project. Should this project be subsequently constructed, the combined dependable yield of Lake Corpus Christi and R&M Reservoirs would be about 293,000 acre-feet annually, which may meet projected municipal, industrial, and limited agricultural demands largely in the Corpus Christi area only to about the year 1985-1990. *Supplemental supplies are thus essential to the future of this region.*

The Texas Water Plan provides for deliveries of supplemental municipal, industrial, and agricultural water supplies to the region through the *Coastal Canal of the Texas Water System.* Ultimately, *at least 283,000 acre-feet* of municipal and industrial supplies would be delivered to the Corpus Christi-Kingsville areas to meet future demands. Additionally, under the Plan approximately *700,000 acre-feet* of water would be delivered to irrigable areas lying north and south of Corpus Christi for project irrigation. Cotton, grain sorghum, numerous specialty crops, forage, and other feed crops would respond to irrigation in this area. Staging of the Coastal Canal to provide for early construction of water supply projects in the Guadalupe and San Antonio River Basins and the Canal from the Guadalupe River to the Lower Rio Grande Valley as proposed by the Plan *could thus avert* impending water shortages in the region. Studies of the potential for desalting for meeting part of the future water requirements of the Corpus Christi area have been conducted, and are continuing. The feasibility and costs of *renovating and reusing municipal wastewater* at Corpus Christi as a means of supplementing existing local supplies are also presently under study by the Water Development Board in cooperation with the U. S. Department of the Interior and private consultants.

In addition to municipal, industrial, and agricultural water supply problems facing the region, *full development and use of the fresh water resources of the Nueces River Basin will further reduce river inflows to Corpus Christi Bay and will affect the estuarine-dependent life and productivity of this bay system.* Careful water-quality management - that is, *strict waste effluent control,* will be essential to gain optimum benefits from the estuarine environment that will prevail. Provided the Texas Water Plan features can be implemented, the proposed Coastal Canal would ultimately provide for *regulated releases* of fresh water into Corpus Christi Bay to replace reductions of natural inflows into Corpus Christi Bay that will result from impending upstream development.

Lower Rio Grande Valley Region

The Lower Rio Grande Valley Region, which includes Hidalgo, Willacy, and Cameron Counties, is basically an *agricultural economy*, although petroleum and natural gas production is an important economic segment in part of the region. Fish and shellfish processing, navigation port facilities at Harlingen and Brownsville, and manufacturing of chemicals also contriubte greatly to the economy. Although irrigated agriculture is by far the leading water-demanding sector of the region's economy, municipal and industrial demands are significant in the urban concentrations. The Lower Rio Grande Valley region of Texas has a great potential for healthy, vigorous growth due to its semi-tropical climate, fertile soils, port facilities, and proximity to the Gulf of Mexico. *An adequate supply of suitable quality water is the limiting factor in such growth, however, and one which will become more critical in the future unless supplemental supplies become available.*

A reported *248,788 acre-feet* of water was utilized by industry in the region in 1968, of which about 1,000 acre-feet was ground water and almost 239,000 acre-feet was saline water. The major demands for industrial water use were for cooling in the generation of electric power (699 acre-feet of surface water) and manufacturing of chemicals (239,000 acre-feet of saline water from the Brownsville Ship Channel). Most of the demand for cooling water is, of course, non-consumptive.

Municipal water demands of the region during 1968 totaled a reported *71,262 acre-feet*, of which approximately 5,200 acre-feet was ground water pumped from the Gulf Coast aquifer. The Cities of Brownsville, Harlingen, and McAllen are the principal municipal users, requiring approximately 12,000, 5,700, and 4,700 acre-feet of fresh water respectively in 1968.

During 1969, 775,460 acres were irrigated utilizing *1,072,661 acre-feet of water*, all but 31,000 acre-feet of which was surface water diverted from the Rio Grande. Ground water supplies in the Gulf Coast aquifer and Rio Grande alluvium are generally saline and unsuitable for continuous irrigation except in Hidalgo County, where supplies are locally of reasonably good quality.

A Treaty between the United States and Mexico encompassing the Rio Grande and the Colorado and the Tiajuana Rivers was ratified by both countries in 1945. This Treaty provides for allocation of the waters of the Rio Grande from Fort Quitman, Texas (near El Paso) to the Gulf of Mexico, between the two countries and also for joint construction of up to three major reservoirs on the main stem for water supply, flood control, and hydroelectric power generation, if needed. The International Boundary and Water Commission administers provisions of the Treaty. In addition, a Compact covering the Rio Grande Basin above Ft. Quitman, Texas was approved by the States of Texas, New Mexico, and Colorado and the Congress in 1939. Since the Compact provides for specific water delivery schedules from Colorado to New Mexico and from New Mexico to Texas, if affects to some extent the amount of water in the river which reaches the Lower Rio Grande Valley of Texas.

Although scheduled deliveries of water under Compact provisions have not been met and the flow of the Rio Grande entering Texas has progressively diminished over the past two decades, completion of *International Falcon Reservoir* in 1953 and *Amistad Reservoir* in 1969 has improved the water supply problems of the basin and resulted in a firm, regulated supply for the Lower Valley. The extensive irrigation which has developed in the Valley has, however, resulted in the shortage of a firm water supply to meet existing permits granted by the Texas Water Rights Commission. Adjudication of water rights in the Rio Grande Basin is presently underway by the Water Rights Commission; however, *in any event the existing agricultural economy cannot be sustained or expanded and fresh water demands which might be created by increased industrialization and population growth cannot be met unless supplemental supplies can be made available for this important area of the Texas coastal zone.*

In order to provide additional fresh water supplies to *"rescue"* existing irrigation, which does not always have a firm supply, and to provide additional water for new irrigation of the vast potentially irrigable lands of the region, the Texas Water Plan provides for ultimate delivery of *700,000 acre-feet* of water annually for irrigation and *150,000 acre-feet* for municipal and industrial use to the region through the *proposed Coastal Canal*. Through early development of certain elements of the Texas Water System facilities, previously described under the Coastal Bend Region, some supplemental supplies could be provided the region possibly by 1990-95.

The flow of the Rio Grande entering the Lower Valley has, however, also been frequently saline largely as a result of irrigation return flows returned to the river from both Texas and Mexico. Nutrient loads and agricultural chemical residues also contribute to a generally poor quality of the river in the region. Although significant improvement in the quality of the river has been accomplished through a recently completed agricultural return flow diversion project in Mexico, the water quality and supply problems remain critical to the region's future. As both an interim and relatively long-range solution to meeting part of the municipal (and to a limited extend industrial) water supply needs of the region, detailed feasibility and costing studies are presently underway for a 8.0 million gallon per day desalting plant in the Brownsville area. This study is being conducted jointly by the U. S. Department of the Interior and Texas Water Development Board in cooperation with the City of Brownsville. Reconnaissance-grade studies of the feasibility of regional desalting plants to serve large areas of the Lower Rio Grande Valley have previously been conducted by the Department of the Interior and the Water Development Board during formulation of the Texas Water Plan. Provided desalt effluent disposal and related potential environmental problems are resolved, the potential for desalting as a means of providing supplemental fresh water for the region is presently considered highly favorable.

TABLES

Water Availability

TABLE 2. 1968 MAJOR MUNICIPAL AND INDUSTRIAL USERS

(Acre-Feet)

County	Surface Water		Ground Water		Saline
	Municipal	Industrial	Municipal	Industrial	Industrial
Orange County					
Allied and Matador Chemical Co.		672		1,221	
City of Orange			3,580		
Equitable Bag Co.				960	9,280
E. I. DuPont DeNemours Co.		15,931		3,184	155,782
Firestone Tire and Rubber Co.		2,191		1,908	
Goodrich-Gulf Chemical Co.				1,510	
Gulf Oil Corp.				2,240	
Gulf States Utilities - Sabine Station		253		1,047	893,505
Owens-Illinois		8,744			
Jefferson County					
Gulf States Utilities - Neches Plant				4,793	288,993
City of Beaumont	10,421				
City of Port Arthur	6,191				
Mobil Oil Co. - Beaumont Refinery		25,472			81,019
Beaumont Industrial		3,979			
Ameripol Inc. (Goodrich-Gulf)		3,066			
Atlantic Richfield Co. (B and P Oil)		3,659			1,043
E. I DuPont DeNemours Co.		9,032			
Goodyear Rubber Co.		5,984			
Gulf Coast Machinery		137			
Gulf Oil Corporation		31,404			112,321
Houston Chemical Corporation		2,716			4,603
Jefferson Chemical Company		11,048			
Mobil Chemical Company		9,735			

Table 2 (continued)

County	(Acre-Feet) Surface Water Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Industrial
Jefferson County Cont'd.					
Neches Butane Co.		2,799			282,625
Texas U.S. Chemical Co.		2,316			
Olin Mathieson Chemical Co.		493			
Sinclair-Koppers Co.		1,921			
Texaco Co. - Port Arthur Refinery		17,800			42,964
Texaco Co. - Port Neches Plant		682			25,779
Texas Gulf Sulphur Co. - Spindletop Plant		7,633			
Texas Gulf Sulphur Co. - Fannett Plant		3,781			
Union Oil Co. - Beaumont Refinery		5,524			11,355
Chambers County					
City of Houston		6,471			
Kole Farms - (Fish Farm)		1,000			
Diamond Shamrock Co.				1,610	
Warren Petroleum Co.				1,290	
City of Anahuac			189		
Cities of Winnie-Stowell			229		
Humble Oil Co. - Anahuac Plant		248			
Liberty County					
City of Liberty		737			
Lone Star Cement Co.		884			
Texas Gulf Sulphur Co.		4,406			

Table 2 (continued)

(Acre-Feet)

County	Surface Water Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Industrial
Walker County					
City of Huntsville			3,111		
Montgomery County					
City of Conroe			1,622		
Humble Oil Co. - Conroe Plant				300	
Jefferson Chemical Co.				443	
Midland Gas Corporation				267	
Harris County					
Ashland Chemical Co.		209		956	
Trinity Portland Cement Co.				346	1,534
Gulf Oil Corp. - Cedar Bayou Plant		2,885			
Olin Mathieson Chemical Co.				5,242	19,334
City of Houston	33,315	77,942	147,079		
City of Baytown			4,969		
City of Bellaire			2,864		
City of Clear Lake City			1,087		
Phillips Petroleum Co. - Adams Terminal		2,370			
Houston Power & Light - San Bertron Plant				385	243,700
Houston Power & Light - Deep Water Plant				966	58,400
Houston Power & Light - Webster Plant				123	142,300
Armco Steel Corp.				10,399	36,696

Table 2 (continued)

(Acre-Feet)

County	Surface Water		Ground Water		Saline
	Municipal	Industrial	Municipal	Industrial	Industrial
Bayport Water System				1,415	
Champion Papers, Inc.		42,721		7,248	
Crown Central Petroleum Co.				3,032	
Diamond Shamrock Corp. - Greens Bayou Plant				1,228	
Diamond Shamrock Corp. - Deer Park Plant				8,435	135,405
E. I DuPont DeNemours Co.				5,026	
Ethyl Corp.				6,472	13,465
Houston Lighting & Power - Hiram O. Clarke Plant				1,425	
Houston Lighting & Power - Greens Bayou Plant				2,296	
Houston Lighting & Power - T. H. Wharton Plant				4,888	
Humble Oil and Refining Co. - Baytown Refinery				8,972	
Ideal Cement Co. - Houston Division				1,253	
Lubrizol Corp.				5,242	
Petrotex Chemical Corp.		12,597		2,175	
Phospnate Chemicals Inc.				1,412	
Rohm and Haas Co.				5,370	
Shell Chemical Co. - Deer Park Plant				8,363	
City of Galena Park			1,292		
Shell Oil Co. - Houston Refinery		10,205		6,083	
Signal Oil & Gas Co. - Houston Divisicn				8,639	

Table 2 (continued)

County	Surface Water (Acre-Feet)		Ground Water		Saline
	Municipal	Industrial	Municipal	Industrial	Industrial
Sinclair-Koppers Chemical Co.				3,422	
Atlantic Richfield Co.				1,897	
Arco Chemical Co. - Lyondell Plant				6,963	
Southland Paper Mills, Inc. - Houston Plant				18,294	
Stauffer Chemical Co. - Harrisburg Station				2,459	
Stauffer Chemical Co. - Industrial Chemicals Div.				1,443	
Tenneco Hydrocarbon - Chemicals Div.				5,100	
U.S. Industrial Chemicals Co. - Deer Park Plant				1,859	
Eastex Oaks			1,029		
City of San Jacinto City			1,055		
Memorial Village			1,398		
N.A.S.A.			1,368		
City of South Houston			1,651		
City of West University Place			2,076		
City of Pasadena			7,734		
<u>Galveston County</u>					
City of Galveston			12,923		
City of LaMarque			1,514		
City of Texas City			4,934		
Gulf Chemicals and Metallurgical Corp.				1,069	

Table 2 (continued)

County	Surface Water (Acre-Feet) Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Industrial
Marathon Oil Co.				2,256	
Texas City Refining, Inc.				3,020	
Houston Lighting & Power –					
P.H. Robinson Plant				639	332,200
American Oil Co.		22,972		754	
Monsanto Chemical Co.		8,470		3	98,972
Borden Chemical Co.		1,087			
Todd Ship Yards Corp.				149	1,344
Union Carbide Corp.		21,421		535	
Brazoria County					
City of Alvin			1,138		
City of Angleton			1,061		
City of Freeport			1,879		
City of Lake Jackson			1,077		
Dow Chemical Co.		144,260		2,069	2,678,456
Monsanto Chemical Co.		7,693		169	
Pan American Petroleum Corp. –					
Old Ocean Plant		315		723	
Phillips Petroleum Co. –					
Sweeney Plant		6,355			539
Fort Bend County					
City of Rosenberg			1,080		
City of Sugarland	908				
Duval Corp.				4,215	
Jefferson Lake Sulphur Co. –					
Long Point Dome Plant				4,910	

Table 2 (continued)

(Acre-Feet)

County	Surface Water		Ground Water		Saline
	Municipal	Industrial	Municipal	Industrial	Industrial
Fort Bend Utility Co.		12,620		1,125	
Imperial Sugar Co.		707			
Phelan Sulphur Co.				2,411	
Houston Lighting and Power Co. - W.A. Parish Plant		508,900		432	
Waller County					
Humble Oil and Refining Co. - Katy Plant				3,192	24
Prairie View A&M			588		
City of Hemstead			306		
Austin County					
City of Bellville			314		
Colorado County					
Shell Oil Co. - Houston Central Plant				1,130	
Lone Star Cement Corp. - Altair Plant		884		1,326	
City of Columbus				515	
City of Eagle Lake				405	
Superior San and Gravel Co.		783			
Wharton County					
City of El Campo			1,127		

Table 2 (continued)

County	Surface Water (Acre-Feet) Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Industrial
Texas Gulf Sulphur Co. – Wharton Co. Plant		6,068			
May Aluminum Corp.				819	
Matagorda County					
City of Bay City			1,603		
Texas Gulf Sulphur Co. – Old Gulf Plant				3,334	
Celanese Chemical Co.		5,050		46	
Coastal States Gas Producing Co. – Bay City Plant				995	
Lavaca County					
City of Yoakum			806		
Spoetzl Brewery Inc.				91	
Jackson County					
Mobil Oil Corp. – Vanderbilt Gas Plant				222	
City of Edna			758		
Calhoun County					
City of Port Lavaca			1,334		
Alcoa		2,217		2,564	
Union Carbide Corp. – Seadrift Plant		12,779			

Table 2 (continued)

County	Surface Water (Acre-Feet)		Ground Water		Saline
	Municipal	Industrial	Municipal	Industrial	Industrial
Victoria County					
South Texas Electric Co-op, Inc.		24,913		13	
City of Victoria			5,795		
E. I. DuPont DeNemours Co. - Victoria Plant		8,175		1,255	
Central Power & Light Co. - Victoria Steam Power Station		176,888		2,852	
De Witt County					
City of Cuero			812		
Coastal States Gas Producing Co. - De Witt County Plant				123	
Goliad County					
City of Goliad			259		
Refugio County					
Town of Refugio			503		
Humble Oil & Refining Co. - Tom O'Connor Plant				285	4
Bee County					
City of Beeville			1,641		
Getty Oil Co. - Normanna Plant				101	

Table 2 (continued)

	(Acre-Feet)				
	Surface Water		Ground Water		Saline
County	Municipal	Industrial	Municipal	Industrial	Industrial
Pan American Petroleum Corp. - Burnell - N. Pettus Plant				436	
<u>San Patricio County</u>					
City of Sinton			663		
City of Aransas Pass	836				
City of Portland	801				
Reynolds Metals Co.		7,083			
<u>Live Oak County</u>					
City of Three Rivers	286				
Mobil Oil Corp. - Kittie Plant				206	
<u>Nueces County</u>					
Nueces County WCID No. 3 (Robstown)	1,331				
City of Corpus Christi	29,627				
City of Corpus Christi		40,932			
American Smelting and Refining Co.		2,056			
Celenese Chemical Co.		7,089		731	
Centex Cement Corp.		389			1,615
Central Power & Light Co. - Nueces Bay Plant		34			184,575
Central Power & Light Co. - Lon C. Hill Plant		2,219			
Coastal States Petrochemical Co.		3,318			

Table 2 (continued)

County	Surface Water (Acre-Feet) Municipal	Surface Water Industrial	Ground Water Municipal	Ground Water Industrial	Saline Industrial
CPC International Co.		1,534			9,207
Hess Oil and Chemical Corp.		2,018			
PPG Industries, Inc.		2,762			73,653
Pontiac Refining Corp.		2,007			
Southwestern Oil & Refining Co.		1,395			
Suntide Refining Co.		3,860			
McMullen County					
Transcontinental Pipeline Corp.				358	
Jim Wells County					
City of Alice	1,940				
Mobil Oil Corp. - LaGloria Plant				1,105	
Duval County					
City of San Diego			366		
P.P.G. Industries, Inc.				1,444	
Kleberg County					
City of Kingsville			3,448		
Humble Oil & Refining Co. - King Ranch Gas Plant				3,346	

Table 2 (continued)

County	Surface Water (Acre-Feet) Municipal	Surface Water (Acre-Feet) Industrial	Ground Water Municipal	Ground Water Industrial	Saline Industrial
<u>Brooks County</u>					
City of Falfurrias			831		
Humble Oil and Refining Co. –					
Kelsey Gas Plant				251	
<u>Willacy County</u>					
City of Raymondville	815		83		
<u>Hidalgo County</u>					
City of Pharr	131		1,937		
City of Donna	1,249				
City of Edenberg	1,967				
City of Mission	1,480				
City of McAllen	4,747		16		
City of Weslaco	1,850				
Central Power & Light Co. –					
J. L. Bates Plant		3,852			
<u>Cameron County</u>					
City of Brownsville	12,056				
City of San Benito	396		695		
City of Harlingen	5,757				
Central Power & Light Co. –					
La Palma Plant		699			
Union Carbide Corp.		737			238,800
United Foods, Inc.		431			

*TABLE 3. REPORTED AGRICULTURAL WATER USE AND IRRIGATED ACREAGE IN THE TEXAS COASTAL ZONE, 1969.**

Region and County	Surface Water (Acre-Feet)	Ground Water (Acre-Feet)	Total (Acres)	Total (Acre-Feet)
Southeast Texas				
Chambers	128,457	0	51,383	128,457
Jefferson	177,425	0	70,970	177,425
Orange	9,182	1,118	4,232	10,300
Total	315,064	1,118	126,585	316,182
Gulf Coast				
Austin	107	8,129	4,697	8,236
Brazoria	196,080	21,988	69,560	218,068
Colorado	126,075	49,665	42,741	175,740
Fort Bend	24,483	61,386	33,540	85,869
Galveston	19,383	379	6,571	19,762
Harris	14,824	106,703	36,619	121,527
Liberty	68,868	32,960	43,556	101,828
Matagorda	187,942	28,108	55,400	216,050
Montgomery	35	100	135	135
Walker	745	0	1,325	745
Waller	335	28,580	17,759	28,915
Wharton	48,770	190,298	82,253	239,068
Total	687,647	528,296	394,156	1,215,943
Golden Crescent				
Calhoun	37,035	1,544	8,832	38,579
De Witt	225	564	891	789
Goliad	1,076	200	2,695	1,276
Jackson	1,442	114,975	33,750	116,417
Lavaca	77	23,618	8,242	23,695
Victoria	0	17,338	5,385	17,338
Total	39,855	158,239	59,795	198,094
Coastal Bend				
Bee	0	2,106	4,170	2,106
Brooks	0	1,025	1,970	1,025
Duval	10	2,359	4,111	2,369
Kenedy	200	0	400	200
Kleberg	311	329	1,505	640
Live Oak	430	1,679	4,923	2,109
McMullen	0	0	0	0
Nueces	2,630	802	6,301	3,432
Refugio	0	0	0	0
San Patricio	156	6,097	13,839	6,253
Jim Wells	353	2,454	6,385	2,807
Total	4,090	16,851	43,604	20,941

See footnote at end of table.

Table 3 (continued)

Region and County	Surface Water (Acre-Feet)	Ground Water (Acre-Feet)	Total (Acres)	Total (Acre-Feet)
Rio Grande Valley				
Cameron	414,528	0	287,445	414,528
Hidalgo	477,865	31,000	450,292	608,865
Willacy	49,268	0	37,723	49,268
Total	1,041,661	31,000	775,460	1,072,661
Coastal Zone Total	2,088,317	735,504	1,399,600	2,323,821

*Figures based on 1969 irrigation inventory conducted by the U. S. Department of Agriculture, Soil Conservation Service.

*TABLE 4. PROJECTED MUNICIPAL, INDUSTRIAL, AND AGRICULTURAL FRESH WATER DEMANDS IN THE TEXAS COASTAL ZONE, 1990 and 2020.**

(Acre-Feet)

Region	Municipal and Industrial		Agricultural	
	1990	2020	1990	2020
Southeast Texas	749,690	1,667,213	533,500	564,500
Gulf Coast	2,017,106	3,802,227	1,570,000	1,803,000
Golden Crescent	300,000	435,647	233,600	229,600
Coastal Bend	266,211	526,406	575,200	934,500
Rio Grande Valley	136,959	213,422	1,745,500	1,745,500
Coastal Zone Total	3,469,966	6,644,915	4,657,800	5,277,100

**Projections from the Texas Water Plan, Texas Water Development Board, 1968.*

FIGURES

Water Availability

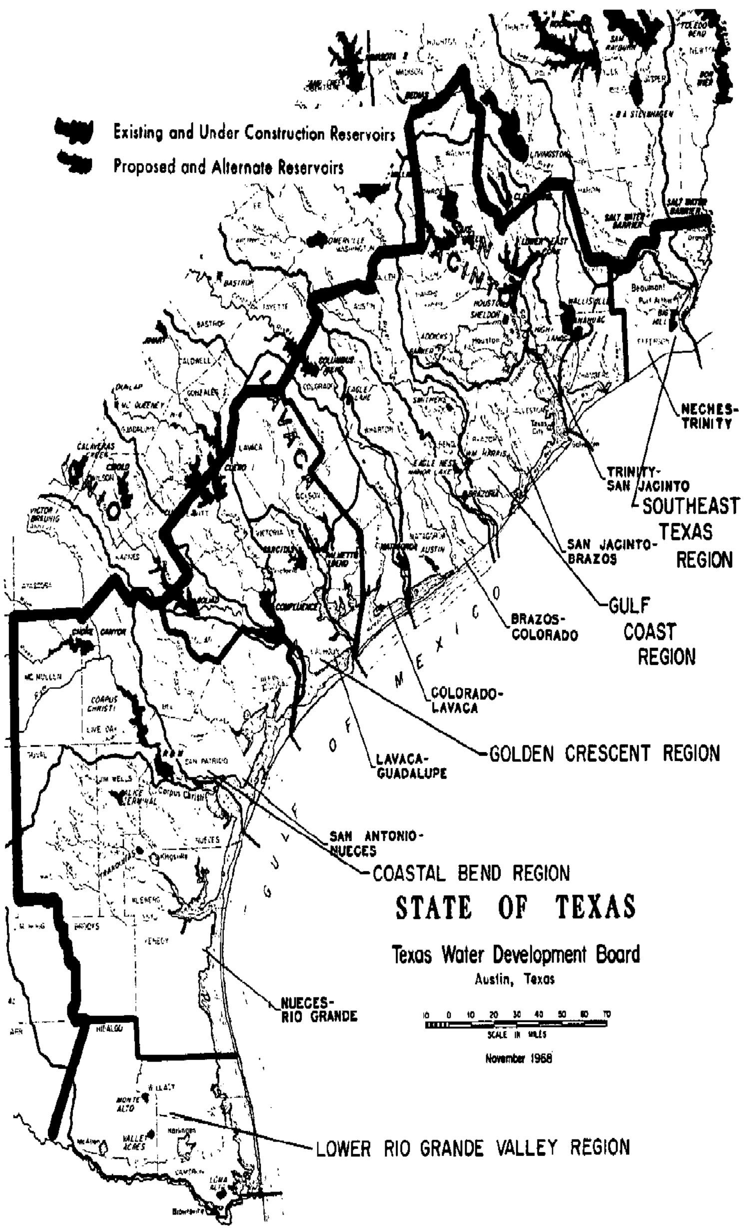


Figure 1

SURFACE-WATER DEVELOPMENT
TEXAS WATER PLAN

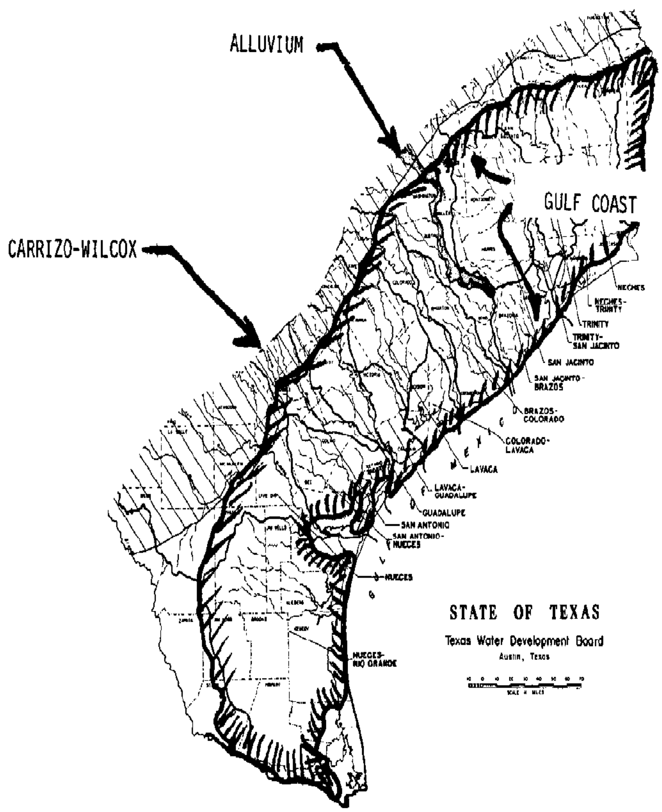


Figure 2

MAJOR AQUIFERS IN TEXAS

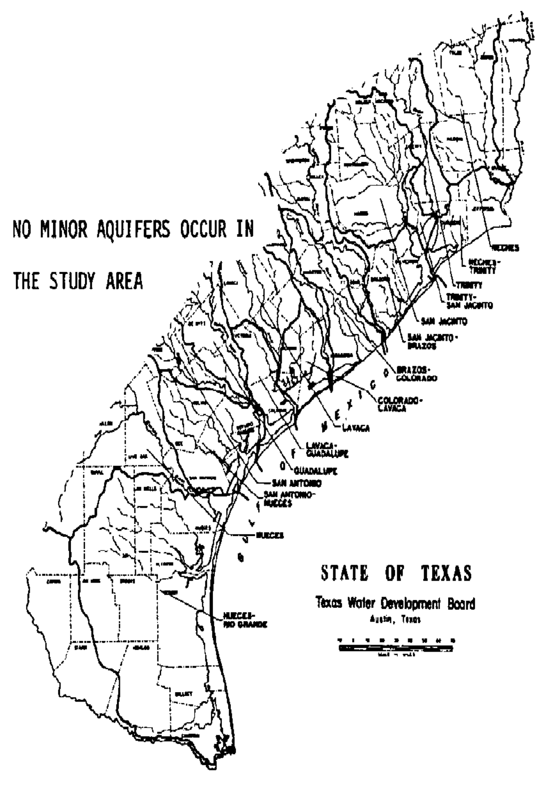


Figure 3

MINOR AQUIFERS IN TEXAS

Figure 4

STEADY WATER LEVEL DECLINE FROM CONTINUED HEAVY MUNICIPAL AND INDUSTRIAL PUMPING

GULF COAST AQUIFER, HARRIS COUNTY

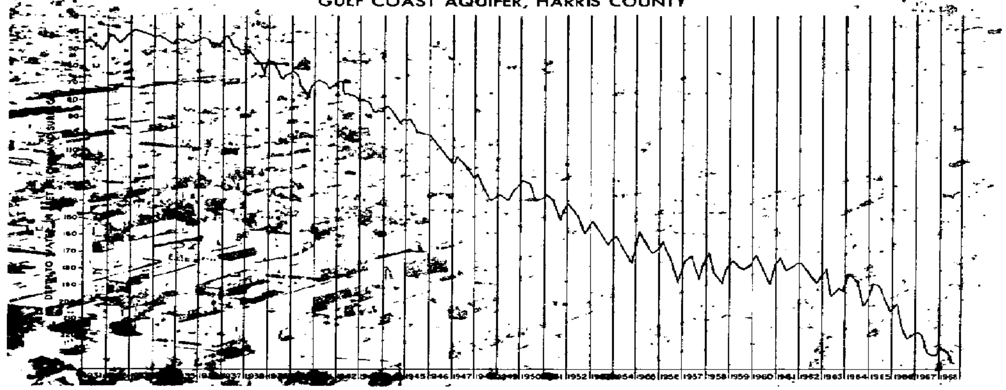
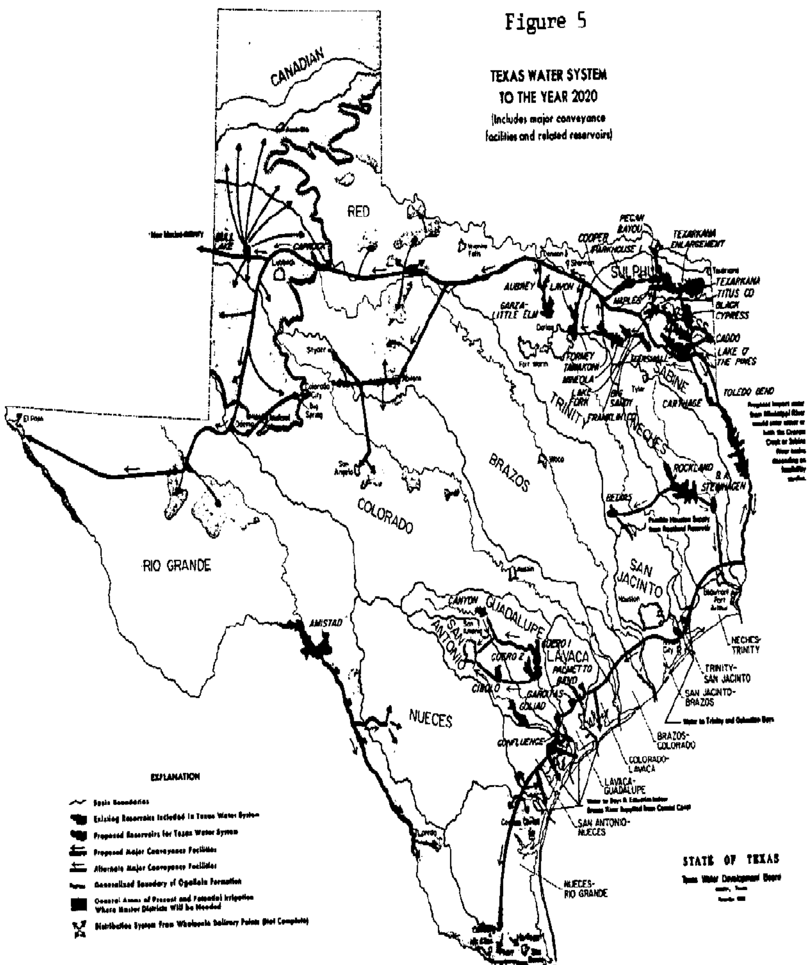


Figure 5


TEXAS WATER SYSTEM
TO THE YEAR 2020
(Includes major conveyance facilities and related reservoirs)
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
NUECES
SAN JACINTO
GUADALUPE
SAN ANTONIO
LAVACA
TRINITY
NECHES
SABINE
SULPHUR
AMISTAD
TOLEDO BEND
ROCKLAND
NECHES-TRINITY
TRINITY-SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA-GUADALUPE
SAN ANTONIO-NUECES
NUECES-RIO GRANDE
EXPLANATION
STATE OF TEXAS

NOTES ON THE TEXAS GULF COAST

AS A TOURISM-RECREATION REGION

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PARKS AND WILDLIFE DEPARTMENT

TEXAS A & M UNIVERSITY

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for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

NOTES ON THE TEXAS GULF COAST

AS A TOURISM-RECREATION REGION

INTRODUCTION

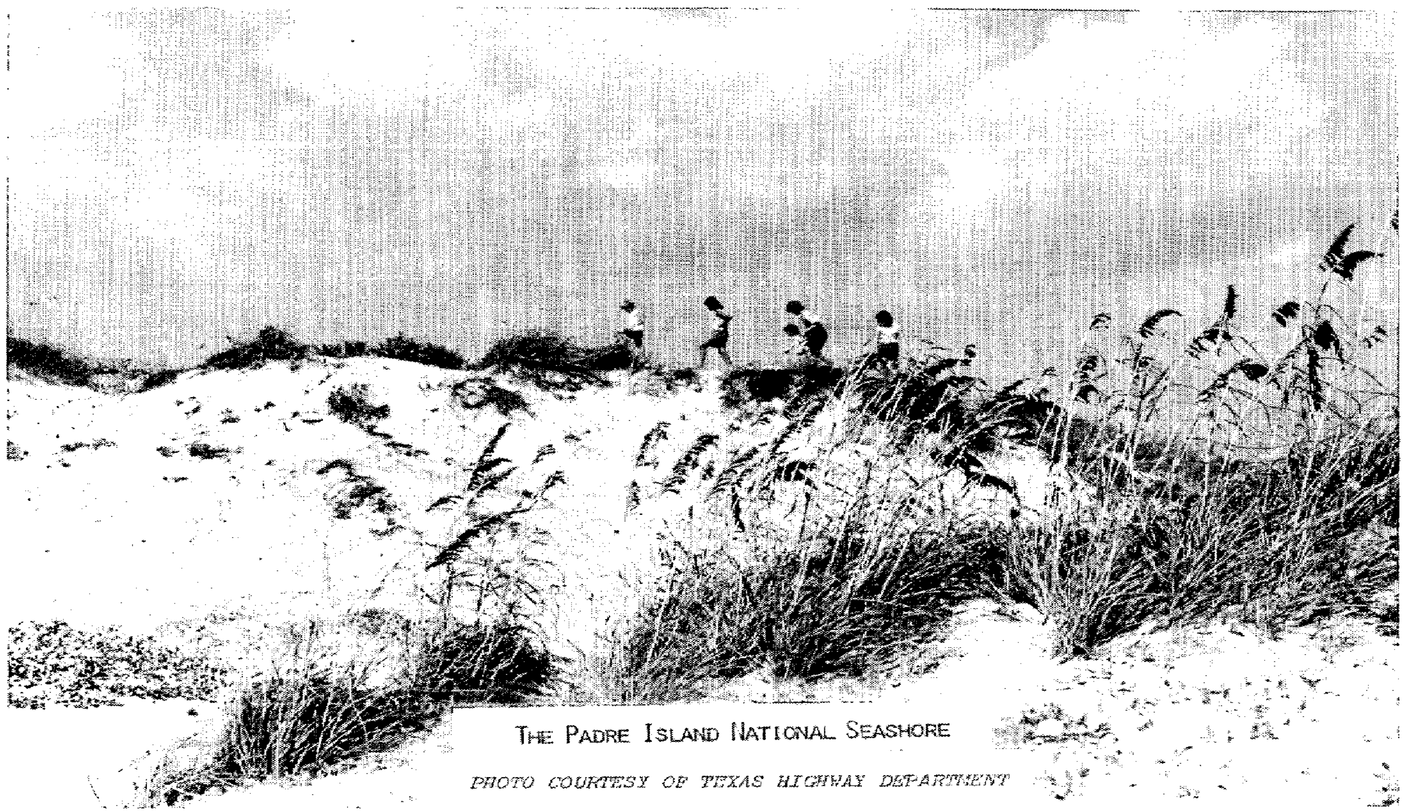
The purpose of this paper is to provide a cursory assessment of the present resource management of the Texas Gulf coast for tourism and recreation. Although tourism and recreation are not synonymous, both involve many of the same land resources, management systems, and groups of users. Both arise from similar factors of human behavior - *the desire to carry on pleasurable non-work activities near and away from home.* For purposes here, the binomial tourism-recreation is construed to include the full range of activity from the most active to the most passive, from the lowest-priced to the most costly, from those heavily natural resource-based to those mostly man-contrived, from indoor to outdoor, and from park and resource "conservation" to exploitation for profit.

Society now demands management of all coastal land for both short and long-range protection of the resource base at the same time it expects greater and greater opportunity for leisure use of the resources. It is no longer willing to accept the role of the terrestrial-marine interface as one great waste system that precludes many uses equally as vital to human life as industrialization.

In the past, tourism and recreation - just as was true of forestry and mining - were assumed to be "free goods," placed at our disposal by Nature for the taking. Items such as scenery, water, fish, mountains, and clean air were gifts and if an area had them it was blessed with opportunities to enjoy them; if not, it had no tourism or recreation.

Now we are recognizing that water, of and by itself, does not create recreation even though it may provide a base for recreation activities. Having a resource asset does not *automatically* provide for recreation any more than iron ore produces automobiles. Modern tourism and recreation are dependent upon the technology and managerial principles that will create the complexes that provide for the human experience sought by people at leisure. Thus, if the resources of a region, such as the Texas Gulf coast are to be husbanded adequately, sound policies of resource evaluation, protection and development must be formulated.

Nationally, there is nothing to suggest a lessening or even leveling of pressure for use of ocean coasts for recreation and tourism. One nationwide study projects an increase of "direct" ocean recreation



The Padre Island National Seashore

PHOTO COURTESY OF TEXAS HIGHWAY DEPARTMENT

activity occasions (swimming, fishing, boating, water skiing, surfing, skin diving) from 689 million in 1965 to 1,121 million in 1980. Many forces now contribute to the desire to make greater use of the Texas Gulf coast in the immediate and long-range future.

USER PRESSURE ON COASTAL RESOURCES

There are several reasons to believe that the coast will continue to be a *population growth* region. This trend is already clear for all coastal regions of the United States. The total population of the 18 counties along the Texas Gulf coast grew by 549,869 between 1960 and 1970, an increase of 23.6%. Increases in development of manufacturing, shipping, mining and tourism hold promise of continued growth of population. Others point to great growth due to processing imported ores.

The development of more tourism and *recreation attractions* is increasing the lure of the region. Already complexes of vacation homes, theme parks, and public parks are being added to the volume of recreational opportunity. Future plans for the region include the installation of several new reservoirs. These will increase the attractiveness of the coast for recreational use, particularly for freshwater activities not now available.

The influential activities of promotion, advertising and publicity continue to increase. The Texas Tourist Development Agency has stepped up its national advertising; a new organization of attractions, The Discover Texas Association, has been formed; and the several coastal cities are increasing their promotional efforts. The publicity accompanying the formation of Padre Island National Seashore has already heightened the public's stepped up awareness of this national attraction.

Recently, there has been a slight increase in the use of *spring and fall* periods for recreational purposes. This may be a clue to greater use in the future as more people in less favorable climates learn of the generally pleasurable weather during these periods. As these vacation times are promoted, there may be even greater in interest in the coast of Texas.

The *image and acceptability* of the South as a destination tourism-recreation region is improving, largely due to more widespread installation of air conditioning and the development of new lures, such as Astrodomain. As the interstate highway system is completed, access from populous regions beyond the coastal region will be made easier. In spite of the recent damaging effects of hurricanes, the attitude toward such natural hazards on the coast does not appear to be negative, as evidenced by the amount of reconstruction and continued growth.

It should be emphasized that these growth pressures are *concentrated in specific locales* rather than widely or evenly dispersed over the Texas Gulf coast. Geographically, recreational growth pressures appear to be following industrial and settlement growth - primarily at two focal points; the Houston-Galveston-Brazoria area and the

THERE ARE 343 MILES OF BEAUTIFUL OCEAN BEACH FRONTAGE WHICH PROVIDE SEEMINGLY UNLIMITED OPPORTUNITIES FOR TOURISTS ALONG THE COASTAL ZONE.

PHOTO COURTESY OF TEXAS HIGHWAY DEPARTMENT

Corpus Christi area. Other nodes are located at Brownsville, Port Lavaca, and Beaumont. Vast stretches of the Texas Gulf coast are yet "undeveloped" in the sense that few permanent structures or land improvements have been installed. Many of these counties actually lost population in the last decade.

A REGION IN TRANSITION

Following a long period of relative stagnation or even reduction in tourism-recreation development, several shifts are now appearing.

Both Corpus Christi and Galveston had at one time a number of large hotels catering primarily to resort destination use. This was comparable to the steamboat-railroad era of resorting in America popular in New York and the Great Lakes region. Although some of these remain, a new resorting expression is appearing as motel, motor inn, and vacation home developments along the coast.

Traditionally, the prime lure of the coast for recreation has been *fishing*. Although this continues to be the greatest use, there is a growing response from non-fishing activities: *surfing, beach lounging, camping, picnicking, shelling, and wildlife appreciation.*

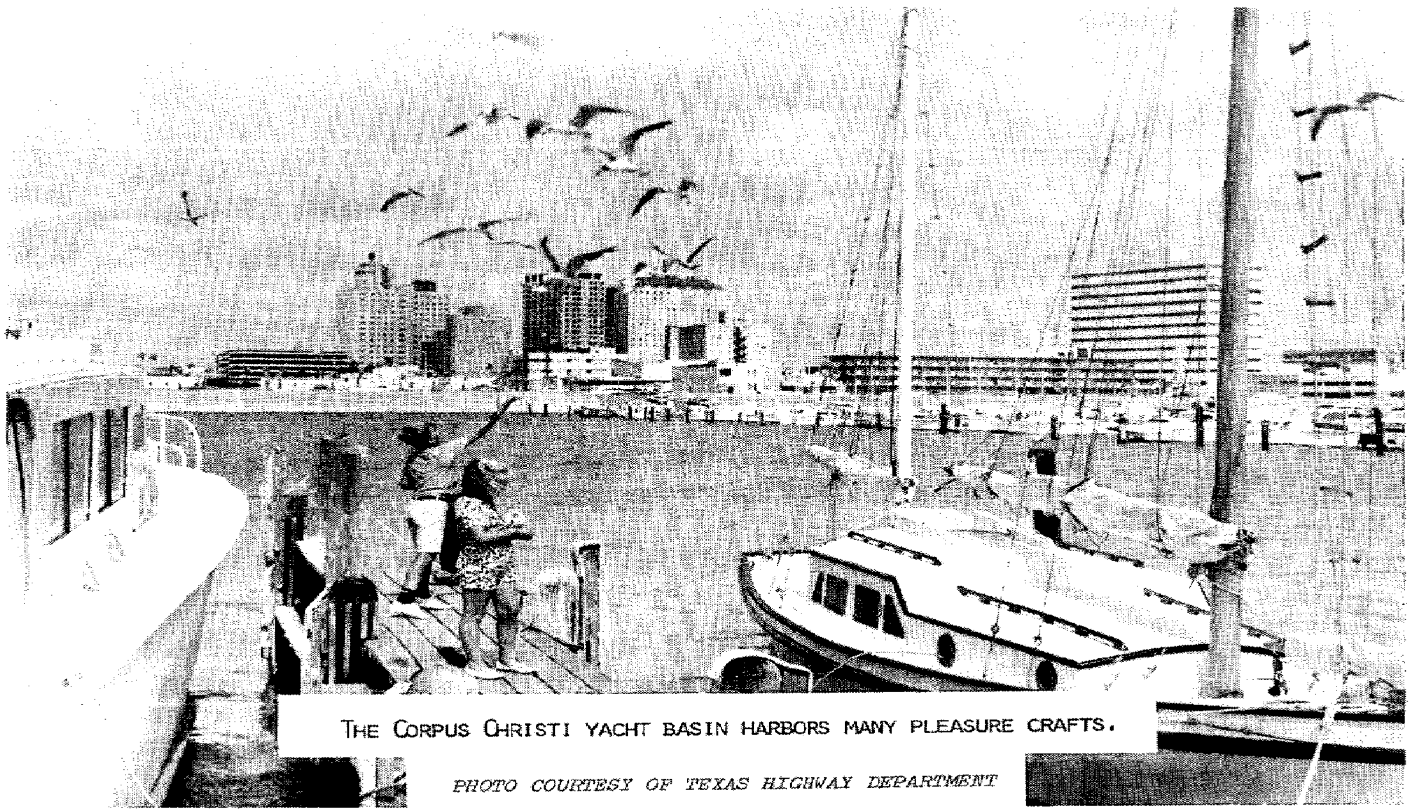
As water pollution, oil production, shell dredging and shipping increase, certain locations are experiencing drastic reduction in quality of resource and therefore quality of recreational experience. *Some localities are now denied any recreational experience at all.*

Gradually, there appears to be increased interest in clustered or packaged types of recreational developments. For example, the county parks, the National Seashore, the theme parks, and historic clusters are becoming more important offerings in the total supply of attractions. In fact, there is growing interest in man-organized and created attraction complexes (either natural resource-based or not) rather than undeveloped raw resources for recreation. For example, the Padre Island natural resources have been there a long time but did not have great visitation until the National Seashore was identified, publicized, managed, and provided with auto access, trails, services and facilities, even though they are now only a fraction of the total planned development.

Internal coastal social changes must be recognized. As minority groups (particularly Latin and Negro) gain status, they become greater participants of recreational areas. This results in some shifts and stratification of use in some of the established recreational areas, especially in city parks.

THE NATURE OF COASTAL RECREATION

If coastal recreation is to be understood, two questions must be dealt with:



THE CORPUS CHRISTI YACHT BASIN HARBORS MANY PLEASURE CRAFTS.

PHOTO COURTESY OF TEXAS HIGHWAY DEPARTMENT

What is unique about coastal recreation generally?

How does the Texas Gulf coast compare with others?

Coastal recreation may be classified three ways: (1) exclusively coastal, (2) general water-oriented, and (3) other. Coastal recreation is like none other by virtue of the land-sea amalgam. The land edge against a major water body represents a special leisure activity base. Here one can participate in such exclusively seacoast activities as surfing, skin diving, underwater exploration, spearfishing, beachcombing, coastal lounging and swimming, coastal hunting, coastal fishing, and general coastal aesthetic appreciation.

Although it has not been documented, it would appear that the latter is a major reason for seeking out coastal areas for recreation. Obtaining the long vistas, watching for ocean-going vessels, feeling the ocean breezes, contemplating the historic past and legends of the sea, and possibly seeing porpoises or whales on the horizon are some of the lures of seacoast recreation. These are not possible along inland waters.

In addition, coastal waters (including the bays and estuaries) frequently provide many of the same recreational opportunities as do other water bodies: swimming, boating, motor-boating, sailing, canoeing, waterskiing, and fishing. Because these are not exclusively coastal, they can take place on waters near or somewhat distant from the seashore. For example, wherever a new reservoir is built, it may provide these activities as well as (or better than) the seashore.

It must also be recognized that a coastal region can and often does support many of the same kinds of recreational activity as elsewhere, such as hiking, sunning, bird watching, horseback riding, picnicking, camping, photography, sketching, painting, sightseeing (scenic, scientific, historical), and nature study (biological, geological, botanical) as well as many indoor activities, such as nightlife, conventioneering, visiting friends and relatives, vacation home use, indoor sports, theater and many other urban-oriented leisure activities.

THE TEXAS GULF COAST

The basic natural resource characteristics for exclusive coastal recreational activities are abundant along the Gulf Coast of Texas. Waterfront resources generally are of a quality that would support lounging, beachcombing, and general aesthetic appreciation. Although the topographic, vegetative, aquatic, climatic, and wildlife factors are not spectacular (as compared to other U. S. or world coasts) they are of sufficient quality to offer a reasonable degree of recreational satisfactions when so developed. For populations within Texas and nearby states who are unable to travel to exotic coasts, the Texas Gulf coast represents the only seacoast available to them.

Duck hunters normally get their limit throughout the Coastal Zone.

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

Hunting, fishing and contact marine recreation activities, such as skin diving, underwater exploration, spearfishing and swimming would be possible along much of the coast, bays and estuaries with some notable exceptions. In portions of Galveston Bay, for example, the water quality is so poor that none of these recreational activities can take place.

Extensive stretches of the seacoast consist of such gradual changes in elevation and such finely divided soils that they are mud flats or wetlands for most of the year. These regions are poorly suited to many recreational developments but are well adapted to wildlife types of recreation. Those recreational activities not demanding shoreline resource assets are supported by much of the coastal lands and are already developed to some extent.

On the whole, one can engage in several types of recreational activity if he seeks it out. The total economic significance of investments, trade, and employment oriented to recreational coastal activities is substantial when one considers the public lands, recreation-oriented roads, vacation homes, motels, hotels, restaurants, and marine facilities.

Actually, the unifying characteristics of the Texas Gulf coast as an overall region are weak compared to the strength of subregional entities. The dominant characteristic of the sea provides linkage throughout but historically, economically, and socially, this soon breaks down into segments, generally oriented along river watersheds. The linkage between ocean, bay, estuary, port, port city, river system, and the watershed with its special topographic, climatic, and vegetative characteristics is stronger than is the lateral linkage paralleling the coast. Therefore, any assessment of the Gulf Coast of Texas must recognize the strength of water-based fingers reaching from the coast into the hinterland.

RECREATION AND TOURISM PROBLEMS

Because no major objective study of the Texas Gulf coast has been made to properly assess the limitations or problems of tourism or recreation to date, the following is subject to revision and correction as new information is found. There appears to be a number of situations today that suggest the need for detailed scrutiny of the region to ameliorate or eliminate some of its tourism-recreation difficulties. It is obvious that much is needed to guide the onslaught of growth in this field.

1. *The variety of activities now available appears to be extremely low.* The simpler and more natural-resource oriented activities such as sports, fishing and boating have dominated to date. At many coastal areas it is difficult to find development that allows nature interpretation, industrial tours, recreation vehicle camps, resorts, water-oriented tours, scenic drives, trails, visiting historic sites, obtaining entertainment, and high quality food service and lodging.

SURF FISHING AT MUSTANG ISLAND

PHOTO COURTESY OF TEXAS HIGHWAY DEPARTMENT

2. *Generally, where the resource quality has degenerated the most, the demand for recreation-tourism activity is greatest.* The demand is concentrated in the very place where other demands - manufacturing, shipping, oil drilling, dredging - are increasing pollution both of water and of air. And resource degredation is increasing. In other words, one cannot assume that the great length of the coast and the abundance of shoreline resources are necessarily of equal strength in supporting development and use.

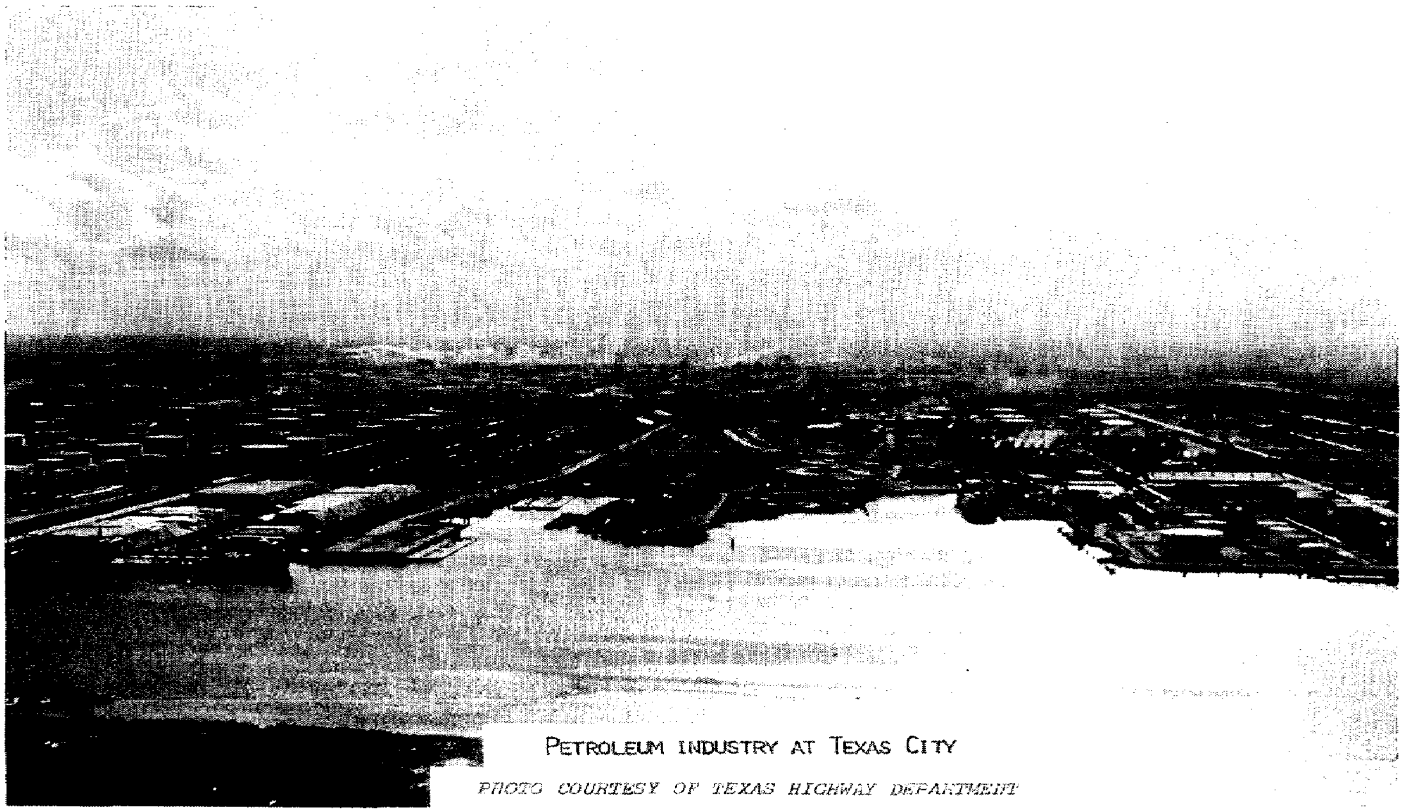
3. *Because there has been no concerted effort toward relating population centers (either coastal or outside) with the coastal resources for tourism-recreation, transportation and access are difficult.* The relatively few public parks and commercial facilities (resorts, motels, marinas) make it difficult for a person to find access to the basic natural resources, particularly the waterfront. One assumption has been misleading - that of "open beach." Prevalent is the fallacy that allowing promiscuous driving and multiple use along the beach is solving access. In affect, the development of a shoreline thoroughfare creates serious internal conflict among those who wish to enjoy the waterfront.

4. *There is little evidence that plans for development have been integrated between separate decision-makers.* Therefore, the *juxtaposition of development* tends to be chaotic, lacking in functional relationship, and aesthetically cluttered. This characteristic of course, occurs dominantly in those areas of the more intense development. But, even in some of the more sparsely developed locations this lack of functional interrelationship is also true. The application of good planning, good site design, good structural design and good management is limited rather than widespread.

5. *There is evidence that no overall guidelines are available to accept the new growth which is inevitably on its way.* If the difficulties of resource erosion and lack of tourism-recreation functionalism are to be corrected and if the opportunities offered by the remaining undeveloped resource base are to be tapped, some overall direction and order must be developed. This is no criticism of present planning forces or those who have already declared an interest in better development of the coast. It is merely a statement of need above and beyond the present effort, particularly directed toward tourism and recreation interests.

SPECIAL STUDY NEEDS

The above review of the situation reveals need for certain special information and insight in order to protect the future valuable resource assets of the unique Texas Gulf coast and assure their wise management for tourism and recreational uses. At least the following four are important at this time.



Petroleum Industry at Texas City

Photo courtesy of Texas Highway Department

1. *Assessment of Tourism-Recreation Management Roles*

Today, a multiplicity of owners-managers-developers control the use of lands throughout the Texas Gulf coast region. Little is known about their policies and practices. Needed is a cataloging and critical review of the many private, public, and non-profit organizations and their management of the present lands and physical plant for leisure use. Only with such data can any overall plans be laid for improvement of the present management. Only with such data can the voids, overlapping, and duplication of management be understood. Only with this information can long-range policies toward resource conservation and protection be developed.

2. *Evaluation of the Potential of the Resource Base*

Needed is an evaluation of the natural and cultural resource base of the Texas Gulf coast for tourism-recreation purposes. A great variety of environmental factors are important to recreation activity. The extent to which these exist on the Texas Gulf Coast has not been determined.

Such a study would provide the foundation for future planning, both by public agencies and by private enterprise. It would not produce a plan but the basis for planning. Such a foundation would identify locations where resource assets clustering, according to tourism-recreation purpose, might suggest strong or weak support. Following this, it would be possible for owner-developers (public as well as private) to prepare individual project feasibilities.

3. *Location of Areas of Critical Need: Protection, Redevelopment*

Because present development of the resource base is not homogeneous, there now exist two types of areas in most critical need for action; those that have not yet been developed and may be of critical value in the future and those that already have reached crisis proportions of resource abuse.

No critical review of the coast has been made to identify those lands that now need to be held from scattered and intensive development in order for them to be available in the future or to maintain a reasonable balance with intensive development. Whether or not such lands are now in public or private hands and the nature of slated development should be determined.

More than emotion is needed to identify clearly those lands (defined to include air, water and land resources) that now

DEGENERATIVE CONDITIONS FOR RECREATION-TOURISM ACTIVITY

PHOTO COURTESY OF TEXAS PARKS & WILDLIFE DEPARTMENT

have reached crisis proportions of resource degradation. A qualitative measure should be applied to rank and locate the most critical areas so that this evaluation can be placed against others for future management planning.

4. *Interrelationships and Social Costs of Alternatives*

Just now we are beginning to recognize the social costs of specific investment and utilization of resources. It is now becoming clear that the disposition of waste products of manufacturing, for example, is a soical cost above and beyond that now included in the balance sheets of manufacturing accouting.

Proposed is the examination of pilot sites and locations and the development of models that identify the external as well as internal costs of several likely alternative and interrelated land uses. This type of calculation can be applied to recreational and touristic uses as well as to agriculture or manufacturing. This device can then be used to evaluate alternative sites for alternative uses as well as alternative uses of the same site.

From such a study could be derived an economic base for making changes in controls and management of land uses along the Texas Gulf coast.

CONCLUSIONS

This brief examination of recreation and tourism along the Texas Gulf coast indicates that these uses are tightly intermixed with other uses of the basic resource assets of the region. There is some homogeneity along the coast because of its relationship with the sea. Other factors, however, support development and management policies that are along subregional watershed lines, running perpendicularly to the coast.

The present level of investment in facilities and services along the coast for tourism and recreation indicate that there is still a chance of redevelopment and restoration as well as new planning that can increase greatly both the quantity and the quality of human experience at leisure. This involves a dedication to reconstruction and guided growth that may not yet exist in the region or at the state level. As a beginning step toward gaining greater foundations and understandings, a minimum of four studies are recommended at the present time: assessment of present management roles; evaluation of the potential of resource base; identification of locations of critical need; and an assessment of land use alternatives as related to social costs.

It should be clear that resource abuse is no longer tolerable and that this coastal region has long ago reached the turning point. If quality settlement for local residents is to continue and if quality experience for visitors is to be attained, new management policies for tourism and recreation must be exercised and soon.

MINERALS AND MINING

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OFFICE OF THE GOVERNOR

CONTENTS

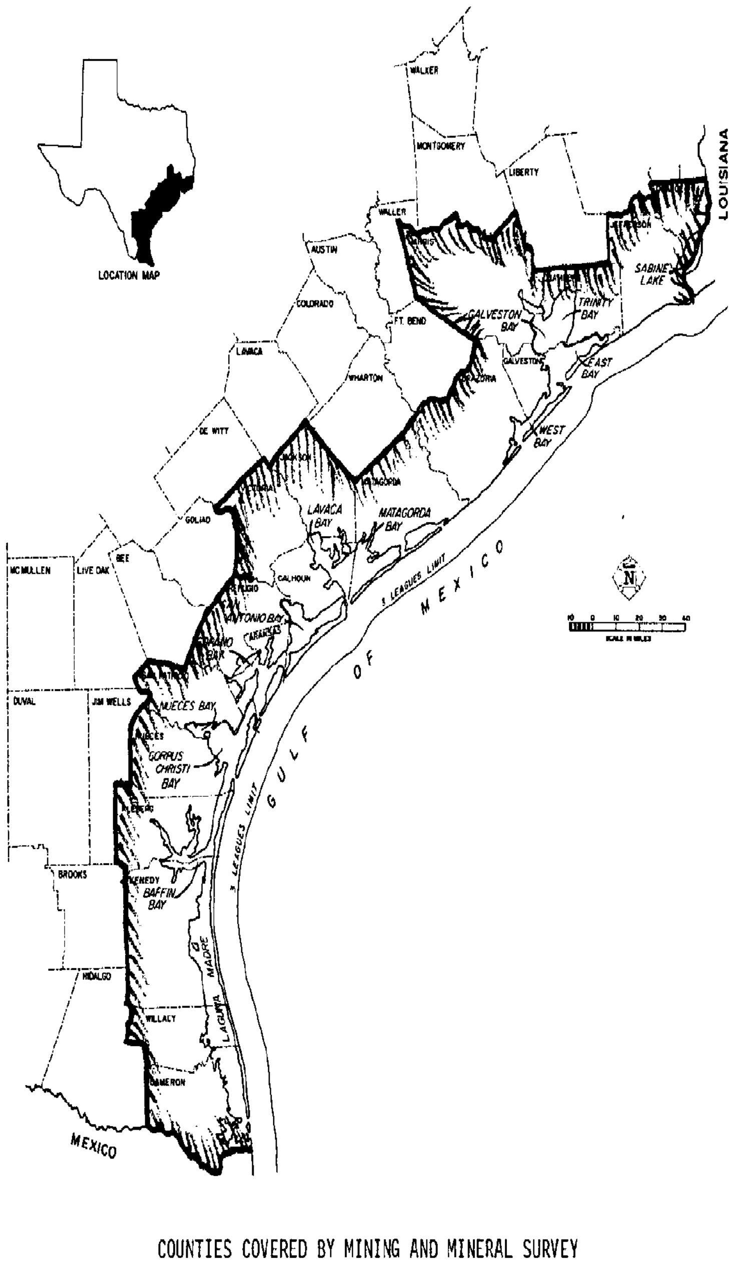
MINING AND MINERALS: TEXAS COASTAL ZONE

I OVERVIEW

Minerals and mining figure very heavily in the total economy of the State. This is especially true of the Texas Coastal Zone, an area richly endowed with natural mineral raw materials, noteably petroleum (oil and natural gas) and chemicals (salt, sulfur, and shell). In the 18-county area bordering marine waters in Texas, direct value of minerals produced amount annually to about *$1.3 billion* or *23 percent* of the total State mineral value; the coastal area includes less than *6 percent* of the total area of the State. The Coastal Zone of Texas contributes nearly *$4 billion* annually in manufactured products, about *35 percent* of the total State value. Minerals provide the overwhelming base for these manufacturing industries, including petroleum refining, petrochemicals, heavy and industrial chemicals, metals and metal products, and primary metals. The mining and manufacturing of minerals in the Coastal Zone and the industries they in turn attract and support result in a concentration of 1/4 of the State's population, accounting for 1/3 of the State's total employment and wages. The Coastal Zone of Texas (18 counties bordering marine waters) accounts for *1/3 of the total economy of the State concentrated in 1/20 of its total area.*

The mineral endowment of the Coastal Zone is enhanced by its geography. Ocean ports permit import of a variety of mineral raw materials attracted by abundant sources of relatively cheap fuel and power. The same ports permit extensive export of both raw and manufactured mineral products. On the other hand, the geography of the Coast is a limiting factor. *Twenty percent* of the Coastal Zone has been inundated by salt water from major storm surges in the past decade; low-lying land and marshes pose special problems in engineering, drainage, and waste disposal; salt water encroachment affects the water supply; natural constructional aggregates (consumed at an annual per capita rate of about 7 tons) are virtually lacking; transportation canalization, waste disposal, and dredging alter the physical, chemical, and biologic environment of the bays and estuaries. Problems of noise, air pollution, surface excavation - common to mineral and other industries also exist. Thus, exploitation and utilization of the Coastal Zone's vast meneral endowment is not without limitations.

The Coastal Zone of Texas, for the statistical purposes of this section, include the 18 counties of the Texas coast that border marine waters (bays, inlets, and offshore). These include: Aransas, Brazoria, Calhoun, Cameron, Chambers, Galveston, Harris, Jackson, Jefferson, Kenedy, Kleberg, Matagorda, Nueces, Orange, Refugio, San Patricio, Victoria, and Willacy Counties. Also included in the Coastal Zone, as here used, are submerged areas of Texas bays, estuaries, and offshore regions.



COUNTIES COVERED BY MINING AND MINERAL SURVEY

II SPECIFIC MINERAL RESOURCES AND COMMODITIES

The principal mineral resources of the Coastal Zone include (in approximate order of value of production): crude oil, natural gas, sulfur (native and secondarily recovered), salt, chemicals extracted from sea water (magnesium and bromine compounds), shell, constructional aggregates and fill materials, and common clay. Value of production of these materials in the 18-county area of the Coastal Zone with listing by county and minerals produced is given in Table 1. Distribution and occurance of major mineral resources and existing mineral industries are shown on an accompanying map (Plate I).

A. PETROLEUM AND RELATED PRODUCTS

Oil and natural gas: Oil and natural gas constitute the major energy and raw material source for the present and future development of the Coastal Zone. Value from the production of these minerals figure paramount in the area's economy, accounting for more than 90 percent of the $1.3 billion in annual mineral value of the area. In addition to direct economic contribution, oil and gas support numerous other industries in providing feedstock or fuel supply. A large number of industries exist in the area that supply materials and equipment to the oil and gas industry.

Crude oil is produced from all counties of the Coastal Zone, with present production coming from more than 3,200 fields and pools (Tables 2 and 3 and Plate I). *The 18-county area of the Coastal Zone has accounted for nearly 20 percent of the total crude oil production of the State with cumulative production through 1968 of about 5.7 billion barrels.* Daily production from the Coastal Zone amounts to approximately 561,000 barrels, ranging from as little as about 30 barrels daily in Cameron County to as much as 7,300 barrels daily in Refugio County. Nearly half the counties of the Coastal Zone have more than 200 presently producing fields. Brazoria, Chambers, Harris, Jackson, Kleberg, and Refugio Counties have daily production in excess of 50,000 barrels; Galveston, Jefferson, Matagorda, Nueces, San Patricio, and Victoria Counties exceed 10,000 barrels in daily production.

Principal production of crude oil is from the Frio trend running approximately parallel to the present coast. The intersection of this trend and large salt domes account for the most prolific production. Most of the major fields produce from salt dome structures. Of the 97 fields in the State with actual or estimated ultimate recovery of 100 million barrels of oil or more, 23 occur within the 18-county area of the Coastal Zone.

The crude oil production of the Coastal Zone supports an extensive oil refining industry. *Of the 47 petroleum refineries in the State, 31 are located in the Coastal Zone.* These are especially concentrated in the Houston and Beaumont-Port Arthur areas. Approximately 120 oil field equipment and machinery plants exist in the area to support the oil industry.

Natural gas is produced from approximately 4,900 fields and pools in the Coastal Zone, and from all counties (Tables 2 and 3 and Plate I).

Table 1. VALUE OF MINERAL PRODUCTION, TEXAS COASTAL ZONE
(from Bureau of Economic Geology, Mineral Res. Circ. 51, 1969)

(Thousands)

County	1967	1968	Minerals produced in 1968 in order of value
Aransas	$ 9,304	$ 14,260	Petroleum, natural gas, natural gas liquids, shell.
Brazoria	218,312	232,265	Petroleum, natural gas liquids, natural gas, salt, magnesium chloride, bromine, magnesium compounds, lime, sulfur, sand and gravel.
Calhoun	28,638	21,451	Natural gas, petroleum, natural gas liquids, lime, shell, sand and gravel.
Cameron	1,137	1,641	Natural gas, petroleum.
Chambers	99,403	89,064	Petroleum, natural gas, salt, shell, natural gas liquids, clays.
Galveston	59,261	57,437	Petroleum, natural gas, natural gas liquids, shell, clays, sand and gravel.
Harris	130,694	127,514	Petroleum, cement, natural gas liquids, natural gas, salt, lime, sand and gravel, clays.
Jackson	77,363	82,461	Petroleum, natural gas, natural gas liquids.
Jefferson	87,098	74,864	Petroleum, sulfur, natural gas, natural gas liquids, salt, sand and gravel, shell, clays.
Kenedy	11,888	18,170	Natural gas, petroleum, natural gas liquids.
Kleberg	136,068	171,248	Petroleum, natural gas, natural gas liquids.
Matagorda	81,913	81,459	Natural gas, petroleum, natural gas liquids, shell, sulfur, sand and gravel.
Nueces	87,594	98,536	Natural gas, petroleum, natural gas liquids, cement, lime, shell, sand and gravel.
Orange	12,778	10,979	Petroleum, cement, natural gas, clays, natural gas liquids.
Refugio	108,936	102,866	Petroleum, natural gas, natural gas liquids.

Table 1. (continued)

County	1967	1968	Minerals produced in 1968 in order of value
San Patricio	43,075	44,107	Petroleum, natural gas, natural gas liquids, sand and gravel stone, clays.
Victoria	32,530	25,229	Petroleum, natural gas, sand and gravel, natural gas liquids.
Willacy	10,228	12,173	Petroleum, natural gas, natural gas liquids.
Coastal Zone Total -	$1,236,220	$1,265,724	
State Total -	$5,406,371	$5,505,831	

Table 2. OIL AND GAS PRODUCTION, TEXAS COASTAL ZONE*

County	Cumulative Production of Oil Through 1968 (bbls)	Number of Producing Fields	
		Oil	Natural Gas
Aransas	57,556,324	114	159
Brazoria	817,957,191	162	221
Calhoun	62,390,411	106	230
Cameron	117,834	2	29
Chambers	575,563,200	264	274
Galveston	301,595,685	94	136
Harris	931,668,035	164	215
Jackson	361.512,673	337	463
Jefferson	383,451,069	160	230
Kenedy	13,217,938	90	144
Kleberg	178,451,710	315	269
Matagorda	177,441,111	321	371
Nueces	439,999,223	495	778
Orange	100,101,693	41	30
Refugio	645,771,416	223	452
San Patricio	369,856,574	319	366
Victoria	178,971,955	233	439
Willacy	64,681,703	54	101
Offshore State	** 3,667,831		
Offshore Federal	** 5,260,164		
TOTAL	5,669,233,740	3,236	4,907

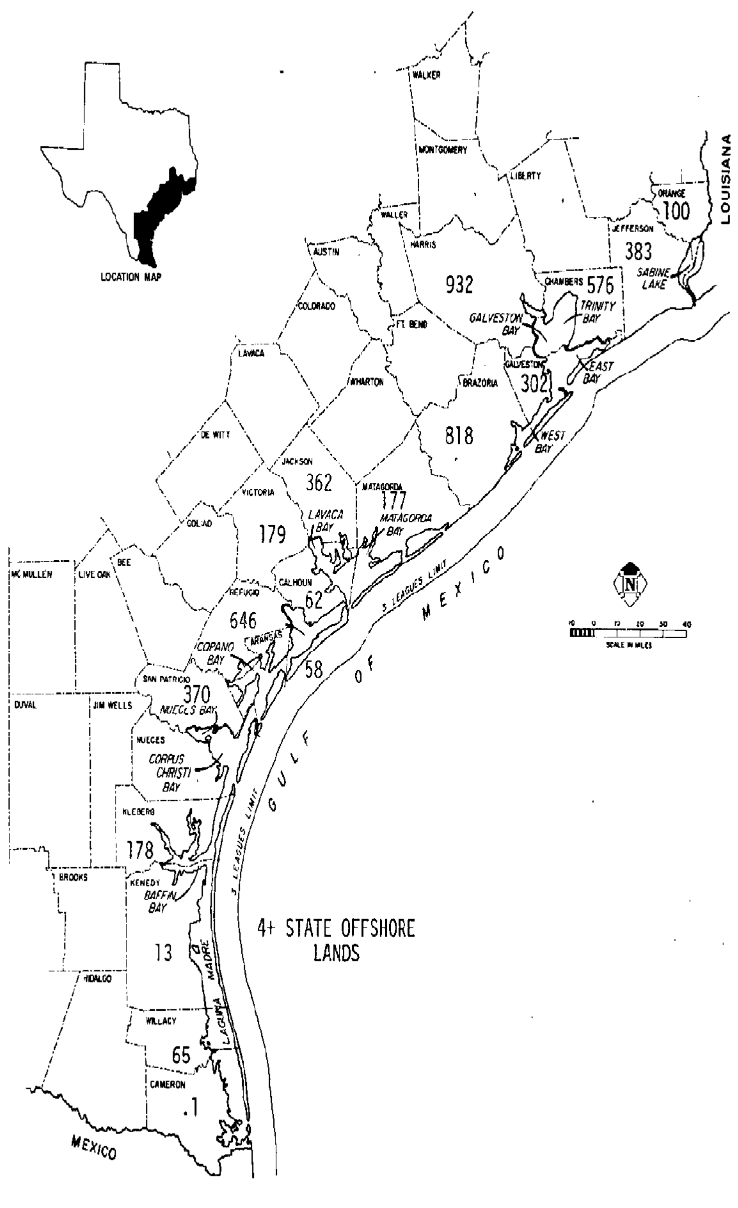
* Source: Texas Mid-Continent Oil and Gas Association and Texas Railroad Commission

** includes cumulative production through 1969

Table 3. PRODUCTION OF PETROLEUM AND NATURAL GAS IN TEXAS COASTAL ZONE, 1969 *

County	Petroleum (bbls)	Marketed Natural Gas (Mcf)
Aransas	1,633,920	40,323,680
Brazoria	21.694,736	280,318,871
Calhoun	2,150,006	74,271,541
Cameron	10,074	18,413,765
Chambers	21,967,788	130,741,005
Galveston	9,440,711	119,081,201
Harris	21,526,338	99,792,151
Jackson	27,512,024	86,161,677
Jefferson	9,004,512	136,961,456
Kenedy	2,557,608	85,729,989
Kleberg	22,897,028	478,910,945
Matagorda	7,847,184	233,196,100
Nueces	8,489,154	320,271,905
Orange	1,681,395	12,498,432
Refugio	30,347,546	132,661,108
San Patricio	9,491,089	58,249,670
Victoria	4,316,958	53,150,500
Willacy	2,410,184	35,020,332
TOTAL	204,978,255	2,395,754,328

* Source: U. S. Bureau of Mines and Texas Railroad Commission



CUMULATIVE OIL PRODUCTION (millions of bbls) THROUGH 1968

Approximately 200 fields produce natural gas in excess of 1 million cubic feet daily. Principal concentration is in the central part of the Coastal Zone extending from Nueces north through Brazoria Counties. A significant part of the total production of natural gas from the Coastal Zone is exported out of State. Natural gas is processed at 50 plants in the area; products include natural gasoline, liquid petroleum gas, cycle condensates and derived liquids.

Recent years in the Coastal Zone of Texas have been marked by a general decline in exploration and developmental activity, although variations in amount of activity vary from year to year. During 1968 a total of 923 wells were drilled in the 18-county area of the Coastal Zone and offshore areas (Table 4). More than 60 percent of the total wells drilled were development wells in proved fields. Approximately 70 percent of all development wells drilled were successes; about 18 percent of exploratory wells drilled were completed as commercial wells. Seismic activity has been variable in recent years, but generally within the range of 400 to 500 crew weeks per year. Recent extensive seismic activity in the Texas offshore is down at present. *In overall context, seismic activity is, along with drilling activity, in general decline. Declines in exploration are expected to continue within the present price structure for oil and gas.*

The extent of oil and gas reserves is a matter of paramount importance not only to the State as a whole, but particularly to the Coastal Zone where the existing economy is strongly geared to oil and gas production. Accurate determination of reserves for the specific area of the Coastal Zone is not possible here, but through utilization of existing figures of various sources, reserves of crude oil (including natural gas liquids) are on the order of *3.5 billion barrels in the 18-county area of the Coastal Zone and contiguous offshore areas.* Reserves of natrual gas (including dissolved gas) in the same area are on the order of *50 trillion cubic feet.* Throughout most of the history of oil and gas operation in the Coastal Zone, discoveries have added to reserves in amounts equal to or in excess of production. In recent years there has been a general decline in both oil and gas reserves owing to decline in exploration. Considering future demand and barring several significant discoveries which can come only through more extensive exploration, the general decline in reserves will continue until ultimate depletion of these vital mineral raw materials.

Although the oil and gas trends of the Coastal Zone are mature, chances for additional large discoveries are possible. Potential for the Texas offshore area is not generally felt to be as great as once assumed. Oil and gas will continue to be the principal resource base of the Coastal Zone for several years to come. Decline and ultimate exhaustion is inevitable, and eventual adjustment of the area's economy will be necessary.

Carbon black: Carbon black, manufactured by burning of hydrocarbon liquids or natural gas enriched with oil, is produced at three plants in the Coastal Zone - at Echo, Baytown, and Aransas Pass (Plate I). These three plants produce about 30 percent of the total State production of carbon black; remaining production is chiefly in West Texas. Principal use of carbon black is in rubber products.

Table 4. COASTAL ZONE (18-County Area and Offshore) DRILLING AND SEISMIC ACTIVITY*

		1968	1967
	Oil	265	324
Proved Field Wells	Gas	136	176
	Dry	166	137
	Oil	30	42
Exploratory Wells	Gas	46	104
	Dry	280	361
TOTAL		923	1,145
Seismic Crew Weeks		500	400

*Source: Bureau Economic Geology Min. Res. Circ. 51, based on data from American Association of Petroleum Geologists, Inc.

B. CHEMICAL RAW MATERIALS

Sulfur: Sulfur occurs within the Coastal Zone as a native sulfur and as sour gas. Native sulfur is the more significant resource of the two in this area; it occurs within the caprock of certain salt domes. Of the 31 major salt domes at relatively shallow depths in the Coastal Zone, 9 contain or contained commercial sulfur deposits (Plate I). Principal concentration is in the upper part of the coast, with 5 sulfur-bearing domes in Brazoria, 2 in Jefferson, and 1 each in Galveston and Matagorda counties.

Native sulfur is produced from caprock deposits by the *Frasch Solution Mining Process;* heated water is injected into the ore body, the sulfur melted, and recovered through return wells, It is shipped either as molten sulfur or allowed to solidify and shipped as solid ore. Sulfur production began in 1912 at Bryan Mound in Brazoria County. Cumulative production since that date is on the order of *130 million long tons;* about 30 million tons have been produced in the 18-county area of the Texas Coastal Zone with the remaining amount from immediately adjoining inland counties. (Table 5)

Sulfur is not commonly used directly by individual consumers, but is used or employed in the manufacture of more than 70 different products. Greatest use is in the production of sulfuric acid. Principal industrial uses of sulfur and sulfuric acid, in approximate order of importance are: fertilizer, chemicals, petroleum refining, paint, metallurgy, rayon and film, pulp and paper, insecticides, rubber, and explosives.

The unit value of sulfur has shown considerable variation in recent years, with fluctuations according to variations in demand and production on the world market. *Presently the price of Texas Frasch sulfur is markedly declining, dropping from an average value of about $41 per long ton in 1968 to about $27 per long ton in 1969.* Yearend prices in 1969 and at present are below the 1969 average.

Specific information on *Frasch* sulfur reserves is confidential and not available. Estimates of 170 million long tons for the entire Gulf Coast area (Texas, Louisiana, and Mexico) have been reported. Certainly less than half this amount is indicated for Texas, and possibly as little as 35 million long tons. A much smaller reserve is indicated in the 18-county area of the Texas Coastal Zone. With the exception of some yearly increases, Texas production of native sulfur has been steadily declining since 1958. *Estimated life of existing known sulfur deposits, assuming a continuation of the production pattern of recent years, is between 10 and 20 years.* Secondary recovery of sulfur from sour gas is increasing substantially in recent years on a State-wide basis and presently accounts for about 20 percent of the total State production. Although some secondarily recovered sulfur is produced in the Coastal Zone, principal districts lie outside the area.

Additional reserves in the Coastal Zone must come from known domes with undeveloped deposits; detailed exploration may expand existing reserves. Another possibility lies with unprospected offshore domes; however, only 5 offshore Texas domes are at sufficient depths for prospecting. Initial exploration of the caprock deposits in certain of these domes has not shown commercial deposits. If discovered offshore, increased cost of production will be a limiting factor.

Table 5. SULFUR DOMES OF TEXAS COASTAL ZONE*

County	Dome	Producing History	(long tons) Cumulative Production Through 1967
Brazoria	Bryan Mound	Freeport Sulphur (1912-35) Hooker Chemical (1967-68)	5,001,068 1,620
Brazoria	Clemens	Jefferson Lake (1937-60)	2,975,828
Brazoria	Damon Mound	Standard Sulphur (1953-57)	139,618
Brazoria	Hoskins Mound	Freeport Sulphur (1923-55)	10,895,090
Brazoria	Nash	Freeport Sulphur (1954-56) Phelan Sulphur (1966-69)	153.115 54,944
Galveston	High Island	United States Sulphur (1960-62) Pan American (1969-)	36,788
Jefferson	Spindletop	Texas Gulf (1952-)	6,854,393
Jefferson	Fannett	Texas Gulf (1958-)	1,942,607
Matagorda	Gulf Hill	Texas Gulf (1919-36) Texas Gulf (1952-)	12,349,597 212,922

*Source: Principally from Myers (1968), in Fourth Forum on Geology of Industrial Minerals, Bureau of Economic Geology, University of Texas at Austin.

Salt: The numerous salt domes of the Coastal Zone provide an almost limitless resource of high-grade sodium chloride. These domes are concentrated chiefly in the upper part of the Texas Coast (Plate I). With the exception of salt mining in West Texas and from two inland domes, all of Texas salt production is from the 18-county area of the Coastal Zone. Salt is mined by solution methods - water injected into the salt mass and returned to surface by brine wells - at Barbers Hill (Chambers County), Bryan Mound (Brazoria County), Spindletop (Jefferson County), and Pierce Junction (Harris County). Salt is mined as a solid ore by underground mining at Hockley Dome in Harris County. *Salt recovery operations are principally near industrial complexes and in areas accessible to water transportation.*

Most of the salt production in the Coastal Zone is as brine and used chiefly as chemical feedstock in the manufacture of chlorine, soda ash, and other chemicals and soap. A relatively small percentage is used in water-softening products, food processing, agriculture, and home use.

Total production of salt in Texas during 1969 amounted to *about 8.6 million tons*, at an average value of *$4.64 per ton*. More than 90 percent of the total State production comes from the Coastal Zone.

In addition to direct value as a mineral resource, salt domes provide, in associated caprock deposits, most of the Coastal Zone production of sulfur, and in stratigraphic and structural traps resulting from salt intrusion, a significant percentage of the oil and gas reservoirs of the Coastal Zone. *Since 1951, cavities created in the massive salt of Coastal Zone salt domes have been used for underground storage of LPG, with domes of the area accounting for about 60 percent of the total underground storage of LPG in the U. S.* Of the 10 domes of the Texas Gulf Coast currently being used for LPG storage, 7 are in the 18-county area of the Coastal Zone (Plate I). Two of the largest operations in the nation are at Barbers Hill in Chambers County; these two operations are equivalent to 1/7 of the total underground liquid hydrocarbon storage in the U. S.

The future of salt production in the Coastal Zone is directly tied to the chemical industry. Reflecting growth of the Coastal Zone chemical industry has been an annual increase in salt production on the order of 6 to 8 percent. Reserves of salt at relatively shallow and accessible depths are practically unlimited in the upper part of the Coastal Zone or from Matagorda County north. In the southern part of the Coastal Zone, shallow salt is limited to inland domes in Brooks and Duval Counties.

Bromine: Elemental bromine was extracted from sea water at the Freeport plant of Ethyl-Dow Chemical for 28 years. The facility was closed late in 1969 as Dow plans to process ethyl dibromide from Arkansas brines. Most of the former Texas production went into production of ethylene dibromide, chiefly for use in antiknock compounds in leaded gasoline.

C. *SHELL: CHEMICAL AND CONSTRUCTIONAL MATERIAL*

The scaricty of two conventional resources necessary to an industrial complex - constructional aggregates and limestone for cement and lime - has led to extensive dredging of shell from Coastal Zone bays and estuaries. Dredged shell is a locally available substitute for these resources with physical properties suitable for use as aggregate and road base and chemical properties suitable for lime, cement, and chemical use. If shell were not used, import of these materials would be necessary.

Shell occurs in the shallow bays of the Coastal Zone from Corpus Christi north to Sabine Lake, either as discrete reefs or banks or as shell mixed with bottom sand and mud (Plate I). Principal shell is oyster *(Ostrea)* with smaller amounts of the clam *(Rangia)*. Parts of certain reefs support living oysters; other reefs consist of dead shell. The dead reefs occur either at the surface or buried in mud at varying depths. Generally reefs are within 10 feet of the water surface and from 5 to 25 feet in thickness.

Shell utilization in the Coastal Zone is a basic part of the existing coastal industry. Initial use began in the late 1800's as a road base. It was first used in the manufacture of cement in 1916 and for lime manufacture in 1929. In the mid-thirties shell was first used in the manufacture of caustic soda, in turn used in petroleum refining and manufacture of aluminum; this use was followed shortly by use of shell in manufacture of glass, soap, plastics, acetate rayon, and glycols. In the early forties shell was burned to lime for reaction with sea water to produce magnesium compounds. All the above uses resulted in increased production. Since the 1940's shell production has increased steadily.

Shell production from Texas bays increased markedly during the 1950's reaching peak levels in the past 15 years, during which *average annual production has been on the order of 11 million cubic yards.* During the past two years a decline in production has occurred with 1969 production at about 8.5 million cubic yards. Cumulative production during the past 50 years is about 275 million cubic yards. About one half of the present total production of shell is u ed as aggregate and constructional base materials. The other half is used in the manufacture of cement and lime. During 1969 shell was used in the manufacturing of more than 13 million barrels of cement valued at nearly *$44 million.* In the same period shell was used in the manufacture of 0.8 million tons of lime valued at more than *$13 million;* lime was used by the chemical industry and as constructional lime.

During most of the history of shell production, *Galveston-Trinity Bay provided nearly 80 percent of the total,* with the remainder coming from Sabine Lake, Matagorda Bay, San Antonio Bay, Nueces Bay, and Corpus Christi Bay. At present prinicpal dredging is in *San Antonio Bay which accounts for about 75 percent of the total production.* Most of the remaining current production is from Matagorda Bay with minor amounts from Nueces Bay and Sabine Lake.

All shell within the submerged waters of the Texas bays is the property of the State. Current royality is 13 to 15 cents depending on shell size. During the past decade the State has collected about *$10 million* in royalities from dredging operators.

Table 6. SHELL RESERVES OF TEXAS COASTAL ZONE

Bay	Currently Reserves	Live Dredged	Commercial Reefs	Oysters
Sabine Lake	small	Yes	No	---
Galveston-Trinity	good	No	Yes	Yes
Lavaca	good	No (past dredging)	Yes	Yes
Matagorda	good	Yes	Yes	No
San Antonio	good	Yes	Yes	Yes
Copano	modest	No	Yes	No
Aransas	modest	No	Yes	Yes
Nueces	depleted	Yes	No	---
Corpus Christi	small	No	No	---

No adequate study to determine shell reserves of Texas bays has been made, though individual dredgers have reserve figures within their immediate areas of concern. Most surveys have been based on probing with a stick or steel rod. Needed for adequate determination of reserves is a combination of *acoustical profiling and coring*. Several factors preclude even a reasonable estimate of reserves: (1) *inadequate* field investigation (profiling, coring, and probing); (2) *variations* in political situations and changes in regulations as to what parts of bays will ultimately be open to dredging; and (3) *changes* in recovery techniques which may make present uneconomic deposits recoverable in the future. The only reasonable good survey of shell reserves has been in Galveston-Trinity Bay, nevertheless, reserve estimates for this bay range from 40 to 90 million cubic yards. Table 6 lists in qualitative terms possible reserves, along with present dredging operations, and occurrence of live reefs, and commercial oyster production. *Regardless of what the total reserves of Texas shell may be, these reserves are finite and at present rates of consumption will be depleted in the not too distant future.* Substitute materials at that time will have to be imported. The nearest source of chemical lime raw materials is central Texas; also the possibility of barge import exists. Constructional aggregate substitutes can be manufactured from clay and other raw materials or imported from inland sources; however, the nearer inland sources of natural aggregates (chiefly gravel) are rapidly being depleted. At present shell contributes a basic raw material to Coastal Zone industry. An adequate survey of reserves and occurrence is needed so that best use can be realized.

D. *CONSTRUCTIONAL RAW MATERIALS*

Natural aggregates and bulk constructional materials: The Coastal Zone of Texas, as in most low-lying coastal areas, is noteably lacking in natural aggregates and bulk constructional materials (sand, gravel, and crushed stone). The Coastal Zone of Texas accounts for nearly *1/3 of the total State consumption* of these materials but only about *1/10 the total State production*. A partial substitute for aggregate exists in local shell deposits and local supplies of fine grained fill sand are plentiful, but gravel and crushed stone must be imported. Most of the gravel supply of the Coastal Zone is from sources up to 50 miles inland along certain of the major streams; crushed stone must be imported from Central Texas. In the southern part of the Coastal Zone caliche is a local substitute for crushed stone but its production and utilization is limited. The existing sources of coarse aggregate (local shell and inland gravel) are rapidly becoming depleted; future supplies must come from farther inland sources. *Unit value for aggregate and bulk constructional materials is low, generally no more than $1.00 per ton; transportation costs, commonly about $0.05 per ton mile greatly increase delivered costs.* Such materials are absolutely essential to the large construction associated with industrial and urban areas; their availability at the lowest possible cost is desirable.

Approximately 4 million tons of aggregate and fill material, valued at about $4.5 million, was produced from the 18-county area of the Coastal Zone during 1969. This total consisted chiefly of fill sand obtained from old stream deposits in the vicinity of the larger urban areas. Reserves of fill sand are large in all areas of the Coastal Zone except in the low-lying marshes.

A possible substitute for natural aggregates can be obtained by the *artificial manufacture* of aggregates from clay. Such clay deposits are numerous within the area. The process involves calcining or partial calcining of the clay to give an indurate material. The artificial product is obtained at a higher cost than natural materials, but will become more and more competitive in price as longer distance imports become necessary.

Industrial sands: Inventory has been completed recently by the Bureau of Economic Geology on possible specialized or industrial uses of sand deposits of the Coastal Zone. Such *specialized uses* as in the manufacture of glass, use as foundry sand, blast sand, chemical feedstock, etc. *command much higher unit price than ordinary constructional fill sand.* At present markets exist in the Houston, Beaumont, and Corpus Christi areas for foundry, glass, and chemical silica sands. These are currently imported from inland sources. Most local deposits of sand in the Coastal Zone will require upgrading and beneficiation to qualify for special industrial use. Modern beach and dune sands of the Texas coast have been locally analyzed for heavy mineral content as possible local sources of ilmenite, magnetite, rutile, etc., but known concentrations are low. More detailed sampling and analysis are needed.

Common clay: Approximately *1 million tons* of common clay, valued at about *$1.3 million* is mined annually in the 18-county area of the Texas Coastal Zone. Thirteen clay mining operations exist at present, with local clays used in the manufacture of portland cement and as raw material for brick and ceramic products. Principal concentration is in the Houston area.

Reserves of common clay within the Coastal Zone are essentially *limitless.* Most of the clays are unsuitable for the manufacture of high-grade structural clay products or fine grade ceramic products, owing to relatively high content of carbonates, iron, and other impurities and to high plasticity. They are of only marginal value for special nonceramic uses such as bleaching clays and drilling muds.

Local clays of the Coastal Zone have been used for manufacture of lightweight aggregate though no plants are operating in the 18-county area at present. The process involves rapid firing with expansion or bloating of the partly vitrified clay to give a lightweight aggregate for such uses as in concrete blocks and precast concrete. At present such use is limited to certain areas just outside the immediate Coastal Zone. Clays are also potential raw materials for artificial aggregates, although cost of manufacture commonly exceeds costs of natural aggregates. As the local natural aggregate supply is exhausted and longer hauls are required, manufacture of clay aggregates from local clays should become more competitive than at present.

Gypsum: Gypsum, a hydrated calcium sulfate used chiefly as a constructional raw material, occurs in caprock deposits of many of the salt domes of the Coastal Zone. Gypsum is not ammenable to solution mining and must be recovered by underground operations. The occurrence of ground water in strata above and around the deposits along with hydrogen sulfide gas severely limit underground mining. Gypsum has been mined from two domes within the coastal area - at Hockley Dome in Harris County and at Gyp Hill in Brooks County (Plate I). About 15,000 tons of gypsum were recovered at Hockley Dome in operations from 1928-30 and 1944-47. Water problems forced abandonment of operations in 1947. Intermittant production between 1929-41 yielded about 350,000 tons from Gyp Hill.

Reserves of gypsum at Hockley and other deeper domes of the Coastal Zone are large and a local market for sizeable production exists. Unless satisfactory methods of underground mining are developed, significant production in the Coastal Zone is unlikely.

E. *IMPORTED RAW MATERIALS*

Primary metals and metallic ores: No metal ore deposits exist in the Coastal Zone other than the use of sea water and potential use of brines in metal extraction. *Ocean facilities for import and export,* relatively cheap and readily available fuel for power source, and an existing market for metal products, result in a diverse primary metals industry in the Coastal Zone based chiefly on imported ores. Primary metal smelters, refineries, and reduction plants in the Coastal Zone are listed in Table 7 and Plate I.

Bauxite is processed to alumina and in turn reduced to metallic aluminum by Alcoa at Point Comfort and by Reynolds at Ingleside; the two companies have a combined annual capacity of 1.1 million tons. American Smelting and Refining smelt *zinc* from imported ores and concentrates, and recover cadmiun as a by-product at Corpus Christi in a plant with annual capacity of 108,000 tons. *Manganese* and *iron* ores are smelted at Houston by Tenn-Tex and Armco; *tin* and *tungsten* ore are treated at Texas City by Lenway in a smelter originally built by the Federal Government in 1942. Magnesium metal is recovered from sea water by a chemical and electrolytic process at two plants of Dow at Freeport; combined capacity of the two plants is 100,000 tons per year.

Barite: Barite, imported from out-of-State sources was processed (ground and crushed) at two plants in Houston, one in Corpus Christi and one in Brownsville. No natural occurrences exist in the Coastal Zone. Use is as an additive in oil- and gas-well drilling muds. Production and output are directly related to demands of the drilling industry.

Perlite and Vermiculite: Perlite and Vermiculite are natural raw materials which upon heating expand to give a lightweight product used as a lightweight aggregate in concrete, plaster aggregate, fillers, and insulation. No deposits of these materials occur in the Coastal Zone, although imported raw materials are processed at plants in Houston.

Table 7. PRIMARY METAL SMELTERS, REFINERIES, AND REDUCTION PLANTS, TEXAS COASTAL ZONE

	County	Material Treated
ALUMINUM		
Aluminum Company of America		
Point Comfort (alumina)	Calhoun	Bauxite (imported)
Point Comfort (reduction)	Calhoun	Alumina
Reynolds Metals		
Sherwin Works (alumina)	San Patricio	Bauxite (imported)
San Patricio (reduction)	San Particio	Alumina
CADMIUM		
American Smelting and Refining	Nueces	Flue dust
IRON		
Armco Steel (Houston)	Harris	Ore (imported) and scrap
MAGNESIUM		
Dow Chemical (Freeport plants)	Brazoria	Sea water (local)
MANGANESE		
Tenn-Tex	Harris	Ore (imported)
TIN AND TUNGSTEN		
Lenway (Texas City)	Galveston	Ore (imported)
ZINC		
American Smelting and Refining	Nueces	Ore (imported) and concentrates

III SUMMARY

The Coastal Zone of Texas contains a variety of mineral resources which contribute massively to the economy of the area either directly in value of produced raw materials or indirectly through the industries they support, supply, and attract. Mineral resources range from those naturally scarce or nearing depletion such as aggregate, shell and sulfur, to those present in almost limitless supply such as salt, common clay, and fill sand. Reserves of oil and natural gas remain large, though addition to reserves has not kept pace with production in recent years. *The decline and ultimate depletion of these basic raw materials will call for fundamental adjustment of the Coastal Zone industrial complex.*

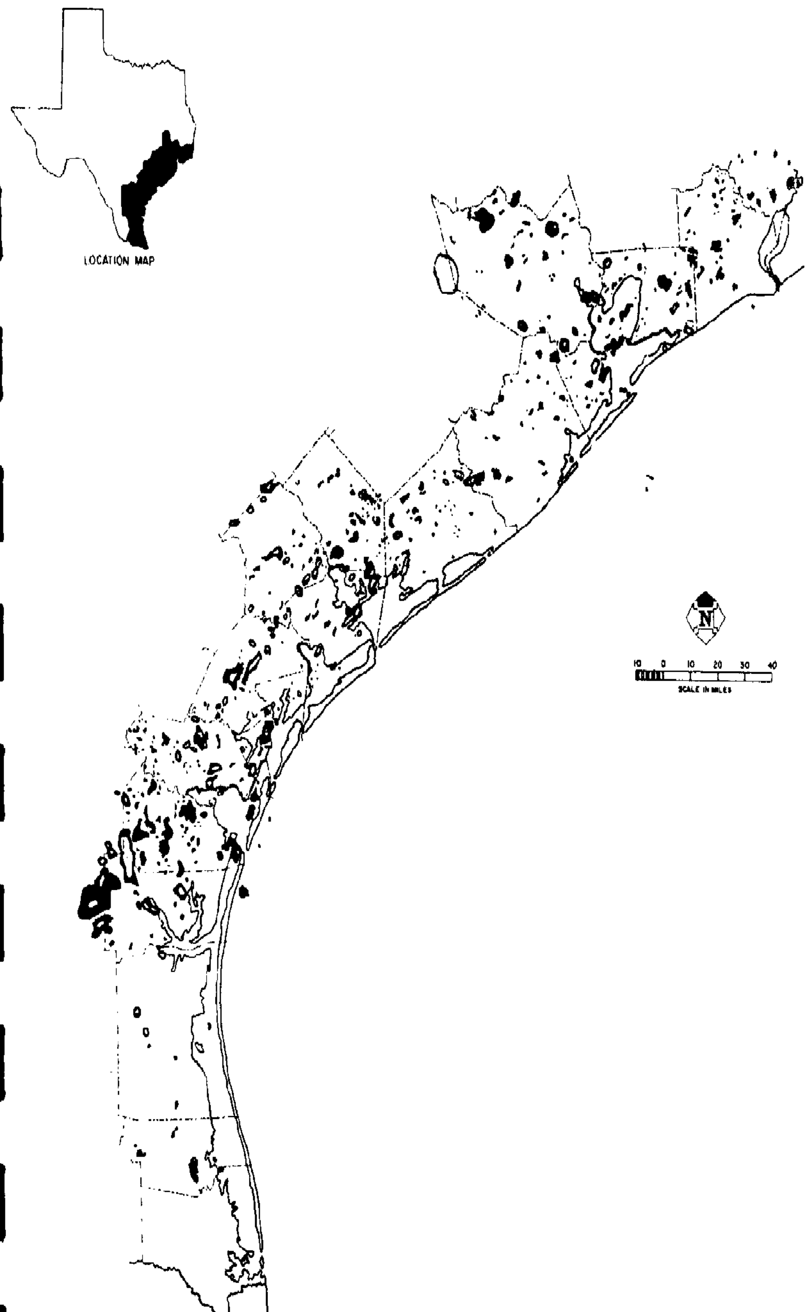


PLATE I-A.

OIL FIELDS IN THE TEXAS COASTAL ZONE

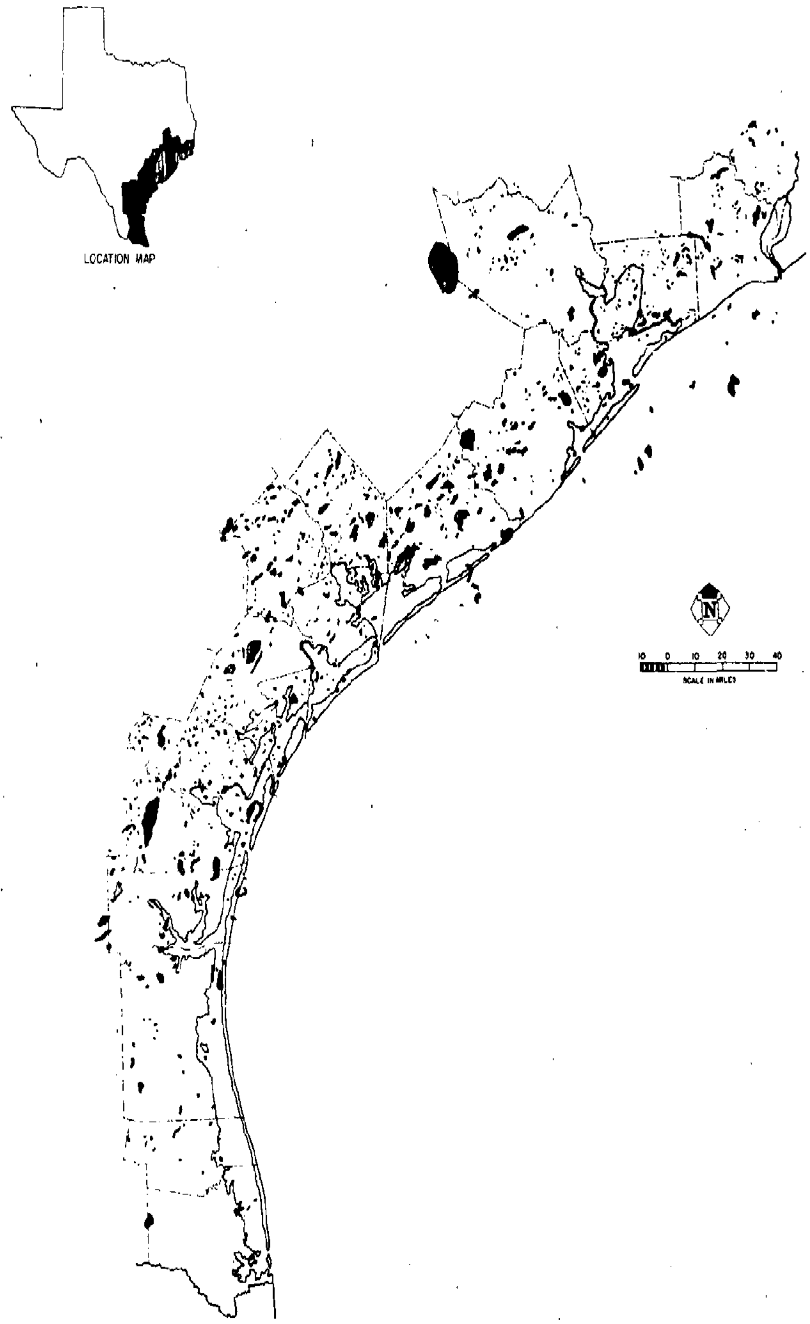


PLATE I-B.

GAS FIELDS IN THE TEXAS COASTAL ZONE

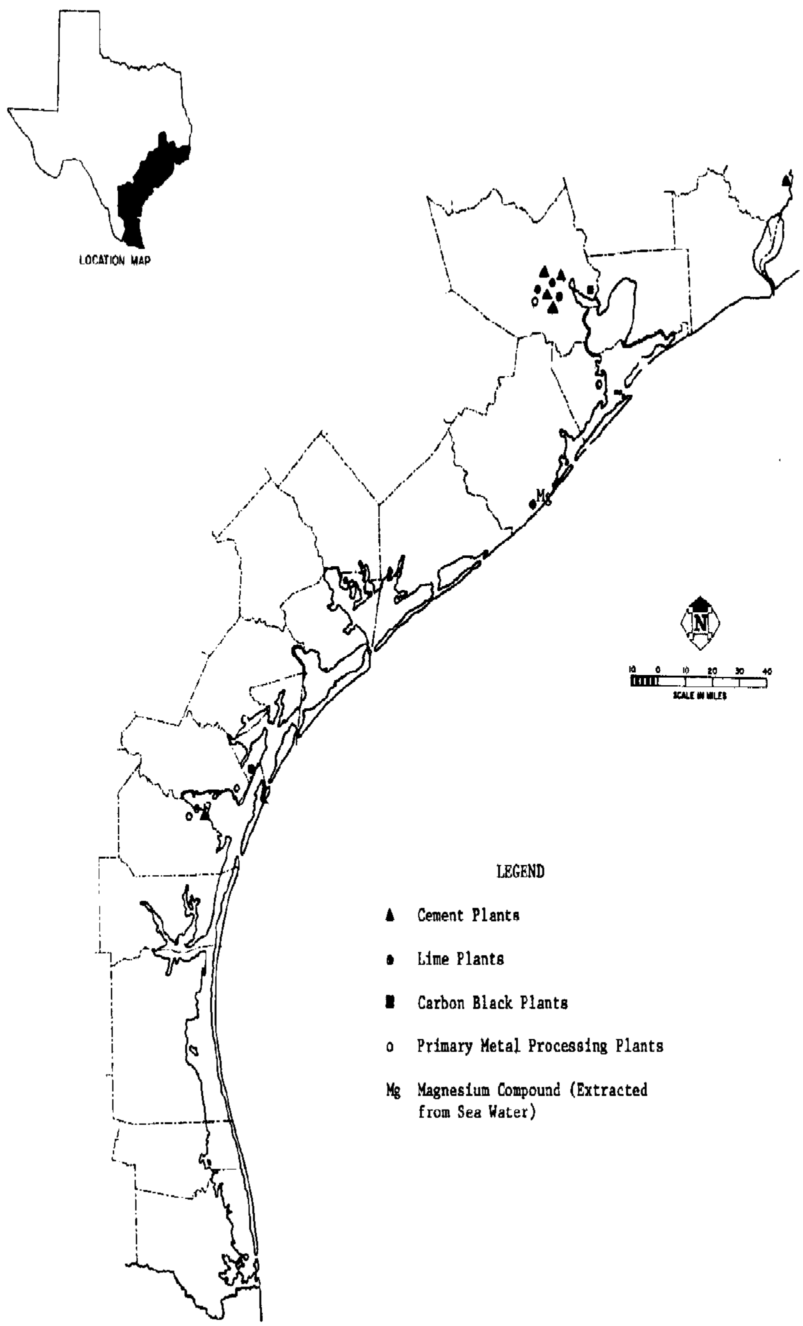
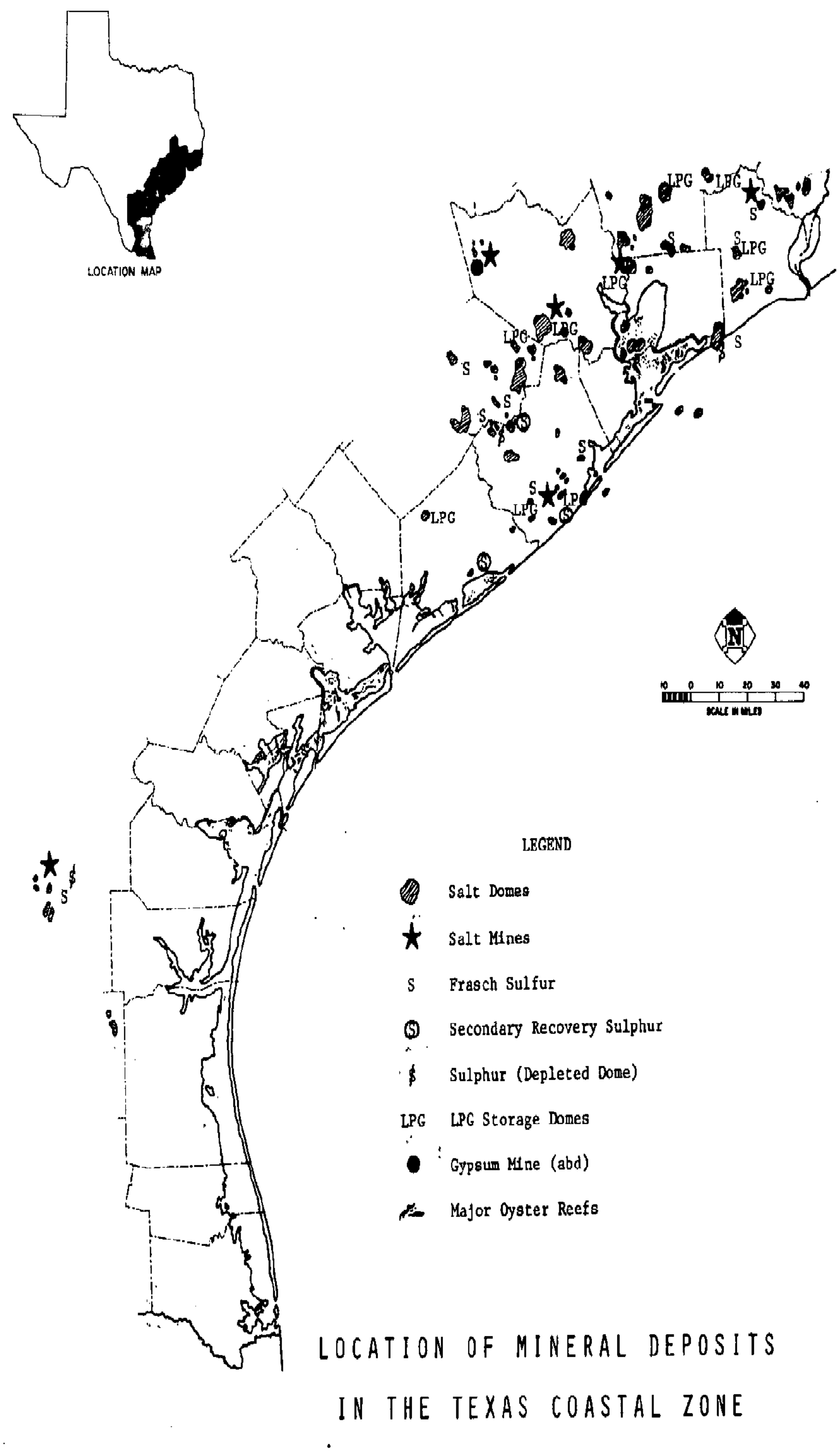


PLATE I-C.

MINERAL PROCESSING PLANTS IN THE TEXAS COASTAL ZONE



LOCATION OF MINERAL DEPOSITS IN THE TEXAS COASTAL ZONE

PLATE I-D.

AGRICULTURE IN THE

COASTAL ZONE

Prepared by

TEXAS AGRICULTURE EXPERIMENT STATION

AND

SEAGRANT PROGRAM

Charles Baker

Jack L. Jones

Jack C. Parker

October 1970

for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

TABLE OF CONTENTS

AGRICULTURE IN THE TEXAS COASTAL ZONE

INTRODUCTION

Agriculture in the Coastal Zone is very diverse, especially if one considers the many developments which may arise as the result developments in mari-culture. This brief report will consist of 4 sections:

I. Overview of Existing Agricultural Production and Expected Trends

II. Shrimp Farming

III. Marine Commercial Fisheries

IV. Appendices: Details of Agricultural Production

I. EXISTING AGRICULTURAL PRACTICES

Traditionally, Agriculture has been the major economic force in the Texas Coastal Zone. In 1969, total cash receipts from agricultural marketings totaled $550,953,000 and Government payments under agricultural programs added $56,570,837 for a total gross return to farmers and ranchers of $607,523,837. Cash receipts are expected to increase more than 30 percent by 1976.

Further impact on the economy is made through purchase by farmers and ranchers of over $400 million of production supplies. About $595 million of value is added to Coastal Zone Agricultural Commodities in processing and distribution operations. *The total income from agribusiness in the Zone was about $1,046 billion in 1969.*

Nineteen million acres or about 90 percent of the total land area in the Zone is classified as agricultural. This land and its improvements were valued at more than $3 billion in the 1964 Census of Agriculture. Off-farm agribusiness facilities are numerous as evidenced by the 202 cotton gins, 88 grain elevators and 10 cotton-oil mills. The cotton gins alone were valued at over $24 million in 1959.

The most important measure of the importance of agriculture to the Coastal Zone of Texas is its people. *The rural population of 1,715,283 in 1970 is about 50 percent of the total population.* Of this number, 71,620 are agricultural workers on the 33,000 farms and ranches. Off-farm agribusiness firms are a larger part of the remaining working forces in the Zone.

Agriculture in the Coastal Zone is more diverse than in any other 36 county areas of Texas. This diversity is influenced by soil, water, climate, urbanization, and the petrochemical and ocean shipping industries. The eastern section contains the rice bowl of the State and the southwestern section contains most of the citrus and vegetable production. Cotton, grain sorghum and beef cattle have important production areas in the Zone and some areas are notable for agricultural diversification.

Rice production in the Zone during 1969 was 21,561,000 cwts, returning an estimated $103,501,000 to farmers. Acres planted to rice numbered about 547,000. An estimated $66.5 million in farm-level expenditures were required to produce this crop.

Cotton production in 1969 totaled 372,035 bales from 560,310 acres with farm value of $61,159,200. Expenditures at farm-level in producing this crop were about $74.6 million. Government payments to cotton farmers in the Zone amounted to $45 million.

Grain Sorghum production was 81.3 million bushels from 1.4 million acres during 1969. Cash receipts of $68.5 million were augmented by $8 million in government payments. Farm level expenditures in producing this crop were about $43.3 million.

Corn production in the Zone during 1969 was about 4.9 million bushels which returned $6,390,500. Farmers spent about $4 million to produce the crop.

There is a significant amount of animal production in the Coastal Zone. There are an estimated *1,830,000 farm animals,* of which 53,500 are milk cows, 1,161,000 are beef cattle, 70,000 are beef calves, 100,000 are hogs, 12,000 are sheep, and 5,000 are ewes. As of 1969, 43 feedlots are operating and they marketed 206,000 head in 1969. Also, 63,000 pounds of wool and 7,000 pounds of mohair were sold. The 53,500 milk cows produced 3,844,700 cwt valued at $25,794. *Other receipts* from farm animals included: hens and pullets - $1,166,000; eggs - $14,633,000, broilers - $3,250,000 and turkeys - $1,658,000.

One citizen elected from each of the 15 counties contiguous with Texas coastal waters act as a Coastal Land Resources Advisory Committee to the Agricultural Extension Service. This committee identified the following agricultural problems, opportunities and research necessary for the development of the coastal land and marshes of Texas on September 10, 1970, at Houston, Texas.

1. Shoreline stabilization research needed.

2. Investigation and selection of vegetation with high

nutritional value adaptable to saline conditions of the coastal marsh.

3. Identification of the effect of agricultural insecticides on estuarine waters, waterfowl, fish and crustaceans of bay waters.

4. Identification relative to effect and cost of drainage of coastal marsh for maximum economic utilization.

5. Investigation needed to identify methods to eliminate brush and noxious weeds, such as Ratama, McCartney Rose, Star Thistle.

6. Investigations needed to determine methods of abating the blowing salt dusts from the Laguna Madre.

7. Feasability of desalination of bay waters for agricultural use.

8. Effects of the dredging of bays on prime habitat of fishes and crustaceans.

9. Investigation of land use controls for maximum orderly development.

10. Investigation of effects of industrial wastes disposal on coastal fish habitat.

11. Identification of new cash crops needed.

II. SHRIMP FARMING *

Shrimp farming may have a future in Texas and thus add to the economic value of the coastal lowlands. Researchers will soon find out through Texas A&M University's Sea Grant Program which will study the economic potential in raising the delicacy on Texas' coastal marshlands and bay shores.

Combined efforts of the Texas Agricultural Extension Service, Agricultural Research Station at Angleton, Brazoria County Mosquito Control District, Commissioner's Court, Texaco and Dow Chemical Company have made possible examination of the feasibility of shrimp farming in Texas on a commercial basis.

There is more enthusiasm for the possibilities of commercial culture of crustaceans than of any other kind of seafood. The market demand for shrimp in the United States, for example, seems insatiable. In 1968 the United States imported 209.5 million pounds of shrimp, almost 30 million more pounds than it

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* Jack C. Parker

produced. In Japan there is a high and growing demand for shrimp, and the Japanese are buying large quantities from many parts of the world.

This strong demand has raised the price of shrimp to high levels. In 1969 the retail price of edible shrimp in Texas ranged from about $1.20 to $1.70 per pound (heads off) and for live bair ' 'om $3.00 to $4.50 per pound. Consistently high market value encourges the hope that profitable culture operations r' be possible.

FARM ESTABLISHED

Funds were made available to the Texas Agricultural Extension Service in September 1968. Texaco provided the site, a marshland area on the West Galveston Bay shore in Brazoria County. Construction of pond levees began in February 1969 with equipment provided by the Brazoria County Commissioner's Court under the direction of J. C. McNeill III, Director of the Brazoria County Mosquito Control District. Natural marsh ponds or "potholes," as well as small reservoirs ranging from 1/2- to 2 1/2- acres, will be used in the study.

Texas' 200,000 acres of coastal lowlands and marshes are especially suited for pond culture because of the high clay content in the soil. Using bulldozers or draglines, ponds can be leveed which will hold water, allowing very little seepage.

Research shows enough shrimp *can be raised in ponds* of this type for *commercial* production. However, pond construction *costs and harvest techniques,* so far, have hindered production. This new program will attack these problems and evaluate stocking rates and food supplements, while looking for economically sound shrimp farming practices.

Initially, ponds will be stocked with postlarvae shrimp (about 1/4- to 1/2-inch long) at a rate of 20,000 per acre. From 80 to 120 days are required to produce a marketable crop. In that time, the shrimp grow to between 5 and 6 inches (25 to 30 shrimp per pound) and yields in experimental ponds in Louisiana have ranged as high as *800 pounds per acre*. The "growing season" is expected to last from late March through early November. Ponds, therefore, can be stocked at least twice during the year.

POTENTIAL GOOD

Three species of shrimp are harvested commercially on the Texas coast: brown shrimp, Penaeus aztecus; white shrimp, Penaeus setiferus; and pink shrimp, Penaeus duorarum. All have farming potential, are marine species and require salt water. With proper acclimation, however, waters of low salinity are suitable for farming.

All three species spawn in the Gulf. The eggs hatch there and pass through three larval stages before emerging as postlarvae which are essentially miniature adults. The postlarvae move into the bays in the early spring. They utilize these waters as a "nursery area" and return to the Gulf to mature.

SEED STOCK PRODUCTION

Postlarvae seed shrimp for experimental farming purposes are provided by the Bureau of Commercial Fisheries at Galveston from female shrimp spawned under artificial conditions in the laboratory. One female shrimp may produce as many as 200,000 postlarvae. Harchery-reared postlarvae are not presently available on a commercial scale; however, a pilot hatchery operated by the Dow Chemical Company should be producing seed stock for experimental purposes this year. It is hoped that this hatchery will be the forerunner to our first commercial operation.

Many pond culture experiments have been conducted using small shrimp captured from the bays, but this method of obtaining seed stock would not be commercially practical because of the necessity to conserve the natural stock for the perpetuation of future generations.

NEW RESEARCH

Most studies now in progress in shrimp culture are intended primarily to facilitate relatively *low-density* practices for use on inexpensive coastal land--synonymous to pasture grazing practices in the beef industry. *In order for industry to participate profitably, however, techniques for a high-density (intensive) culture system--along the lines of a beef cattle feeder lot--are needed.* Both low- and high-density rearing practices are presently employed successfully in catfish culture, and with additional research, techniques for intensive shrimp culture should also be developed. In order to augment the present field efforts of the Texas Agricultural Extension Service, a cooperative project with the Dow Chemical Company will explore the feasibility of an intensive shrimp culture system. Extension personnel presently involved in the mariculture program will cooperate with Dow in this effort and have access to the results of this research.

The possibilities look good to those associated with research in this field. Undoubtedly, many problems will arise as research progresses, but success in these initial experiments could lead the way toward development of a new means of food production and an additional means of utilizing our coastal marshlands.

III. MARINE COMMERCIAL FISHERIES *

INTRODUCTION

Marine organisms that inhabit the seas around the United States constitute some of our most valuable renewable natural resources. Just how long these resources have been harvested by man is unknown, but because of advances in technology and harvesting techniques, the United States in 1968 placed fifth in the total world production of fishery products. Countries that exceeded the United States in fishery production were Norway, China (Mainland), U.S.S.R., Japan, and Peru. *Nevertheless, in 1968, United States fishermen harvested approximately 5.4 billion pounds or about 4 percent of the world catch of fish, crustaceans, and mollusks, etc.*

The United States catch in 1968 was made up of numerous marine species, but dollarwise the five most important in decreasing value were *shrimp, salmon, tuna, crabs, and oysters.* Of these, shrimp, crabs, and oysters were of considerable importance in the Gulf of Mexico and, more specifically, to the fishing industry of Texas. For example, the Gulf States accounted for 73 percent of the total United States shrimp production in 1967. Texas, the greatest producer dollarwise, was followed by Louisiana and Florida. Louisiana produced the greatest volume of shrimp, but because they sanctioned the harvest of shrimp at a smaller size than did Texas, the dollar value was considerably less.

TEXAS SHRIMP HARVEST

Three species of shrimp--brown, white, and pink, comprise the bulk of the shrimp harvest from the Gulf of Mexico. Landings from Texas waters, however, are made up of white and brown shrimp, with the browns predominating. These shrimp are harvested from offshore waters (those over the continental shelf) and inshore or estuarine waters.

Between 1961 and 1967, the total harvest [1] of shrimp offshore increased from *22.3 million pounds (heads off) worth 13.3 million dollars to 55.4 million pounds valued at 38.6 million dollars (Fig. 1).* Despite the slight decrease in landings, in 1968, to 38.6 million pounds worth 33.1 million dollars the trend over the 8-year period from 1961 to 1968 showed an overall increase in shrimp landings from Texas waters.

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* Jack Parker

1 During this period, catches of pink shrimp did not exceed 42,000 pounds.

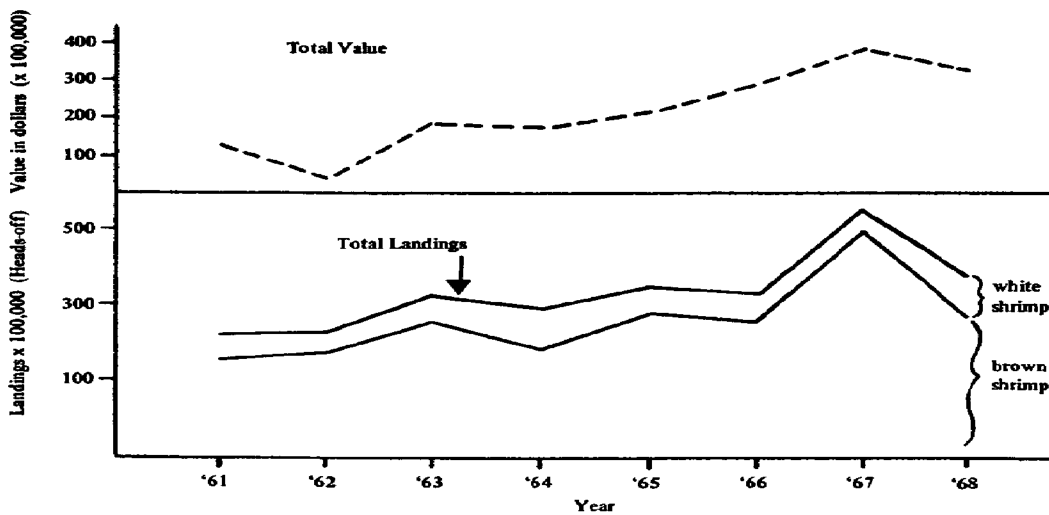

Figure 1. Total pounds, value, and catch composition of shrimp harvested from offshore Texas waters, 1961-1968.

Despite this increase, which is also reflected in total United States shrimp landings, the *consumer demand was not met.* The increasing demand for shrimp was reflected by United States shrimp imports that increased from 134 million to 209 million pounds between 1961 and 1968.

Shrimp taken from inshore or estuarine waters are used for two purposes: bair shrimp for the sportsfisherman, and food. There are a number of Texas estuaries from which shrimp are harvested, yet limited landing statistics are available only for Galveston Bay, an area estimated to produce approximately 50 percent of the total inshore shrimp harvest. The yearly value of shrimp taken from this area for bait and food increased gradually from 3.6 million dollars in 1966 to 5.8 million in 1969 (Table 1).

Table 1. Yearly Landings of Shrimp from Galveston Bay, 1966-1969.

	heads on Bait Shrimp Catch		heads off Food Shrimp Catch		Combined
Year	Weight	Value	Weight	Value	Value
	Pounds	Dollars	Pounds	Dollars	Dollars
1966	785,900	872,900	3,677,300	2,803,400	3,676,300
1967	1,087,800	1,271,800	6,200,600	3,581,600	4,853,400
1968	1,102,600	1,336,800	4,740,100	3,767,100	5,103,900
1969	1,007,500	1,259,375	5,629,500	4,579,000	5,838,375

TEXAS OYSTER HARVEST

Oysters are harvested from a number of Texas bays, but the single greatest producer has been Galveston Bay. Landings from this area have accounted for at least *80 percent* of the total catch between 1961 and 1968. In 1965 Galveston Bay oysters accounted for 95 percent of the states's landings.

Total landings from Texas waters increased from *about 1.0 million pounds in 1961 to 4.8 million pounds in 1965 (Fig. 2).* In the succeeding years, however, landings decreased gradually to 3.3 million pounds in 1968. Values followed a similar trend, but peaked in 1966 rather than in 1965.

TEXAS CRAB HARVEST

As opposed to definite trends in shrimp and oyster landings between 1961 and 1968, there is *no clear-cut trend in crab landings*

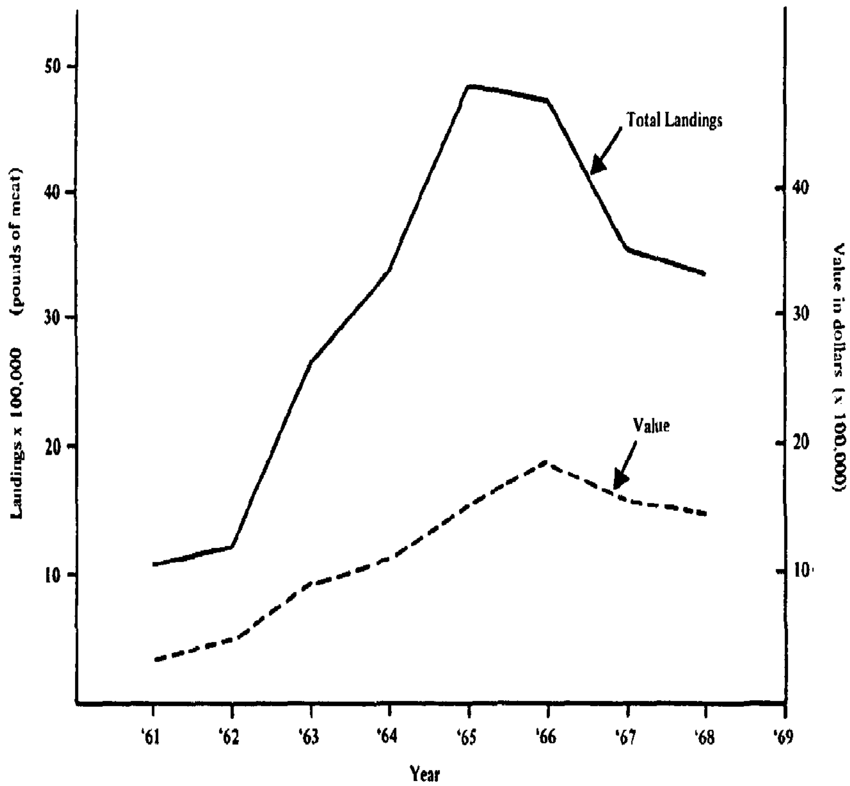

Figure 2. Landings (pounds) and value (dollars) of oysters harvested from Texas waters, 1961-1968.

from Texas waters (Fig. 3). The greatest number of pounds (4.4 million) were harvested in 1962, but the value of the catch was greatest in 1968 when 329 thousand dollars were paid for a harvest of 4.0 million pounds. The only definite trend associated with the harvest of blue crabs has been the gradual increase in processing plants from 4 in 1963 to 12 in 1968.

The reason for the fluctuations in yearly landings is not apparent, but it seems probable that in certain states, particularly Texas, fishermen prefer shrimping to crabbing because of the greater remuneration.

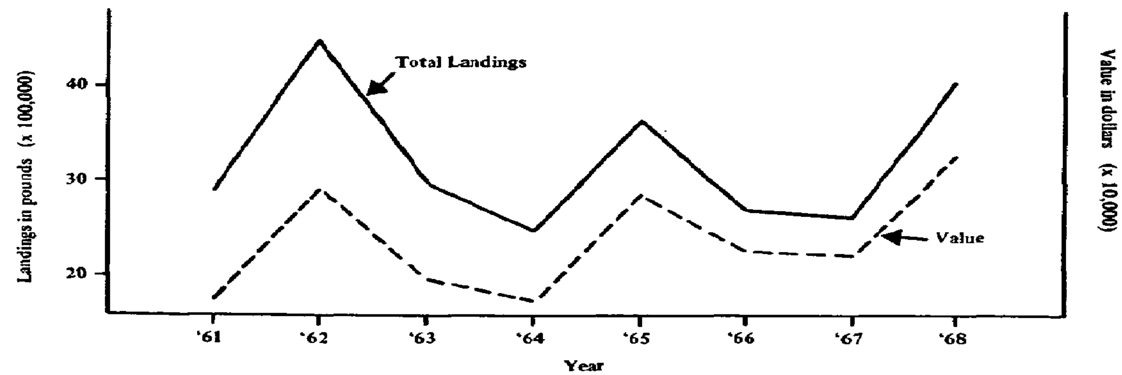

Figure 3. The harvest (pounds) and value (dollars) of blue crabs from Texas waters, 1961-1968.

IV APPENDICES: DETAILS OF AGRICULTULAL PRODUCTION

GULF COAST STUDY REGION

FARM CHARACTERISTICS OF THE TEXAS COASTAL ZONE, 1949-1964

	1949	1954	1959	1964
Number of Farms	49,807	46,101	38,393	33,529
Average Acres per Farm	354.0	388.4	470.9	532.1
Total Land in Farms	17,633,590	17,907,530	18,079,930	17,841,267
Value of Land and Buildings per Farm	$20,470	$34,437	$57,771	$92,079
Total Value of Farm Land and Buildings	$1,229,755,300	$1,587,592,814	$2,218,018,904	$3,087,318,217

Agriculture Census, 1949, 1954, 1959, and 1964

Land Available for Food, Fiber and Forestry Products in the Texas Coastal Zone, 1967

Land Use Classification	Dry (1,000)	Irrigated (1,000)	Total (1,000)
All Row Crops:	2,131	608	2,739
Close Grown Crops	175	564	739
Summer Fallow	1	0	1
Rotation Hay and Pasture	589	560	1,149
Hayland	137	0	137
Conservation Use Only	65	0	65
Temporary Idle Cropland	281	9	290
Orchards, Vineyards, Bush Fruit	8	87	95
Dryland Formerly Cropped	285	0	285
Total Crop Land	3,624	1,877	5,501
Pasture	2,545	34	2,579
Range, Dry	7,382	0	7,382
Forest:			
Commercial	1,842	0	1,842
Non-Commercial	1,197	0	1,197
Total	3,039	0	3,039
Commercial Grazed	1,261	0	1,261
Non-Commercial Grazed	956	0	956
Total Grazed	2,217	0	2,217
Other Land			
In Farms	239	0	239
Not in Farms	450	0	450
Total	689	0	689
Total Land Available for Production of Food, Fiber and Forestry Products:	17,279	1,911	19,190

Farm Production Trends in Texas Coastal Zone: Value of Farm Products
1949-1976

Year	Cash Receipts ($1000)	Percent Change
1949 1/	357,798	
1954 1/	368,951	+ 3
1959 1/	389,184	+ 5
1964 1/	421,175	+ 8
1969 2/	528,072	+ 25
Projected 1976 3/	690,997	+ 31

1/ U. S. Census of Agriculture

2/ Texas Crop and Livestock Reporting Service

3/ Texas Agricultural Extension Service, "3.76 in '76" Program, unpublished data

AGRICULTURAL CASH RECEIPTS IN THE TEXAS COASTAL ZONE;
ESTIMATES FOR 1968-69, PROJECTIONS FOR 1975-76

Commodity	County Cash Receipts 1968	1969	1968-69 Average	Projected Increase 1968-69 to 1975-76	Projected Cash Receipts Average 1975-1976
	$1000	$1000	$1000	$1000	$1000
Cotton	49199.4	53094.6	51147.0	10609.9	61756.9
Cottonseed	9177.7	8064.6	8621.1	1006.7	9627.9
Wheat	231.1	155.6	193.3	80.3	273.6
Oats	76.5	97.4	87.0	53.1	140.1
Sorghum	56147.5	68450.1	62298.8	26295.3	88593.9
Corn	6053.9	6390.5	6222.2	2118.7	8340.9
Soybeans	1509.2	1065.6	1287.4	696.5	1983.9
Peanuts	1232.1	1018.1	1125.1	533.9	1659.0
Cowpeas	107.0	109.0	108.0	50.8	158.8
Broomcorn	381.5	282.9	332.2	0.1	332.3
Flaxseed	1169.4	1838.4	1503.9	317.9	1821.1
Hay	8020.4	7583.1	7801.7	4848.7	12650.4
Nursery	2859.0	3606.0	3232.5	2094.5	5327.0
Sweet clover	0.0	0.0	0.0	41.0	41.0
Vetch seed	7.0	10.0	8.5	12.0	20.5
Rice	136695.7	103501.5	120098.6	17733.9	137832.4
Peaches	14.0	15.0	14.5	75.0	89.5
Figs	108.0	115.0	111.5	10.0	121.5
Pecans	2790.0	294.9	1542.4	982.8	2525.2
Grapefruit	9775.4	12252.4	11013.9	810.0	11823.9
Oranges	8145.3	5286.3	6715.8	493.0	6222.8
Vegetables	42718.0	52289.3	47503.6	20630.3	68133.9
Other crops	412.0	446.0	429.0	286.0	715.0
TOTAL ALL CROPS	336830.	325966.	331398.	88794.	420192.

Commodity	County Cash Receipts 1968	1969	1968-69 Average	Projected Increase 1968-69 to 1975-76	Projected Cash Receipts Avg. 1975-76
	$1000	$1000	$1000	$1000	$1000
Honey	90.0	22.5	56.3	8.7	64.9
Eggs	11139.0	12097.0	11618.0	3014.5	14632.5
Broilers	1725.8	1987.4	1856.6	1393.5	3250.1
Turkeys	1661.2	1481.7	1571.4	86.1	1657.5
Milk	23842.4	25794.0	24818.2	4075.0	28893.2
Wool	145.7	143.9	144.8	0.1	144.9
Mohair	1.7	1.5	1.6	0.0	1.6
Fed beef	23165.7	26262.4	24714.0	5768.4	30482.4
Other beef	111544.0	124960.8	118252.4	41942.2	160194.4
Beef cows	2000.0	2500.0	2250.0	750.0	3000.0
Milk cows	2300.5	2360.0	2330.3	347.0	2677.2
Hogs	4422.8	5425.8	4924.3	4134.0	9058.3
Sheep	109.3	117.0	113.1	5.1	118.2
Goats	9.1	13.1	11.1	6.1	17.2
Hens and pullets	801.2	861.6	831.4	334.4	1165.8
Horses	2924.1	3698.1	3311.1	1901.1	5212.2
Other livestock	2206.3	2206.3	2206.3	1101.2	3307.5
Cockers	800.0	1120.0	960.0	790.0	1750.0
TOTAL LIVESTOCK & LIVESTOCK PRODUCTS	201516.	224987.	213251.	77102.	290354.
Forestry	7694.5	8057.2	7875.8	4361.8	12237.6
Fish farming	92.0	315.0	203.5	2828.5	3032.0
Hunting (leases)	4521.0	5239.1	4880.0	2808.8	7688.8
Fishing (leases)	68.0	69.0	68.5	147.0	215.5
Recreation	252.1	254.1	253.1	1299.0	1552.1
TOTAL CASH RECEIPTS	538346.	550953.	544650.	165896.	710546.

POPULATION CHANGES IN THE TEXAS COASTAL ZONE, 1960-1970

	1960	1970	Percent Change
Urban	1,435,423	1,715,283	19.5
Percent Urban	50	50	
Rural	1,449,603	1,725,702	19.0
Percent Rural	50	50	
TOTAL	2,885,026	3,440,985	19.3

Agricultural Employment in The Coastal Zone of Texas					1965-1969
	1965	1966	1967	1968	1969
Operators and Family Workers in Labor Force	24,980	24,165	23,560	23,155	22,960
Regular Hired Workers	18,215	18,250	18,275	18,295	18,320
Seasonal Hired Workers	33,210	32,460	32,260	28,970	30,360
TOTAL Agricultural Workers	79,845	74,775	74,990	70,420	71,620

ASCS PROGRAM DATA FOR THE TEXAS COASTAL ZONE, 1969

	Number of Total Farms	Cropland Acres	Number of Allotment Acres	Number of Partici- pating Farms	Allotment Acres in Partici- pating Farms	Diverted Acres in Partici- pating Farms	Number of Loans	Units Under Loan	Amounts Disbursed
All Farm Data	62,805	6,496,063							56,570,837
Agricultural Con- servation Program		587,977		6,746					2,774,801
Crop Land Adjust- ment Program		28,430		193					444,440
Soil Bank Con- servation Reserve		4,244		31					53,957
Peanut Acreage Allotments		178,229		524	223,839				
Rice Allotments and Supports		545,470		1,973	548,391		1,975	6,128,012 (cwt)	28,947,479
Upland Cotton Program	27,103		955,947	22,005	939,033	12,322[a/]			45,025,731
Feed Grain Program	31,154		1,719,082	7,508	583,136	267,915			8,233,803
Wheat Program	83		344	6	56	25			266
Corn Price Supports							4	5,195 (bu)	5,752
Sorghum Price Supports							176	646,077 (cwt)	1,194,512
Honey Price Supports							6	74,349 (lbs)	9,789
Soybean Price Supports							2	16,506 (bu)	36,583
Cotton Price Supports							1,004	22,950 (bales)	2,372,775
Wool and Mohair Program							475	168,233 (lbs)	29,964

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LIVESTOCK PRODUCTION IN THE TEXAS COASTAL ZONE

	Inventory of Farm Animals January 1, 1969	January 1, 1970
	(head)	(head)
All cattle	1,878,000	1,830,000
Milk cows, 2 years and over	54,800	53,500
Beef cows, 2 years and over	1,105,000	1,161,000
Beef calves on feed	77,000	70,000
Hogs	125,000	100,000
Sheep	13,000	12,000
Ewes, 1 year and over	6,000	5,000

	Feed Lot Capacities and Livestock Product Marketings 1968	1969
Number of feed lots	48	43
Feed lot capacity (head)	152,000	139,000
Fed beef marketings (head)	178,000	206,000
Wool (pounds)	74,000	63,000
Mohair (pounds)	12,000	7,000

COTTON PRODUCTION IN THE TEXAS COASTAL ZONE

	1968	1969
ACREAGE		
Planted	475,330	560,310
Harvested	425,440	516,750
YIELD PER ACRE		
Planted	256	331
Harvested	285	360
PRODUCTION (500 # BALES)	242,450	372,035
CASH RECEIPTS ($1000)[a/]	169,857	141,291

a/ Includes cotton lint and cottonseed

Grain Sorghum Production in the Texas Coastal Zone

	1968	1969
Acreage:		
Planted	1,299,700	1,427,300
Harvested	1,180,800	1,314,700
Yield per Harvested Acre	48	62
Total Production of Grain (1,000 bu.)	56,802	81,270
Value of Grain Produced ($1,000)	56,148	68,450

* Value of grain production in 1976 is projected at $88.6 million.

Dairying in the Texas Coastal Zone

Number of Milk Cows (2 years and over)	
January 1, 1969	54,800
January 1, 1970	53,500
Milk Production (cwt)	
1968	3,870,890
1969	3,844,700
Cash Receipts from Milk Sales ($1,000)	
1968	23,842
1969	25,794
Projected 1976	28,893

Poultry Products in the Texas Coastal Zone

	1968	1969	1976
Hens and Pullets (1,000 hd.)	1,757	1,444	
Cash Receipts ($1,000)	801	862	1,166
Eggs (1,000 dozen)	32,649	24,569	
Cash Receipts ($1,000)	11,139	12,097	14,633
Broilers (1,000 hd.)	3,025	2,694	
Cash Receipts ($1,000)	1,726	1,987	3,250
Turkeys (1,000 hd.)	569	490	
Cash Receipts ($1,000)	1,661	1,482	1,658

Specified Farm Expenditures in the Texas Coastal Zone, 1964

Item	Expenditure ($1,000)
Feed for Livestock and Poultry	
Feed grains	8,715
Commercial feeds	28,813
Hay and Roughage	5,568
Total	43,096
Purchase of Livestock and Poultry	
Livestock	25,227
Poultry	2,362
Total	27,589
Seeds, Bulbs, Plants and Trees	10,940
Fertilizer	20,746
Fuel and Oil	23,165
Machine hire	18,820
Hired Labor	45,495
Total Specified Expenditures	189,851

U.S. Census of Agriculture, 1964.

Irrigated Rice: Value at farm-level of expenditures for production imports normally included in budgets

ITEM	VALUE (Mil. Dol.)
Seed:	
Home Produced	1.44
Purchased	4.33
Custom Service:	
Irrigation	5.45
Aerial Application	2.73
Drying	8.25
Fertilizer	8.44
Pesticides and Herbicides	4.44
Fuel and Oil	3.52
Tires	.37
Batteries	.09
Repairs and Farm Machinery	3.63
Gas Companies	2.01
Electricity	.46
Repairs to Electric Motors	.19
Interest on Operating Capital	1.72
Depreciation on Machinery and Equipment	9.27
Hired Labor	7.07
TOTAL	66.51

LAND OWNERSHIP PATTERNS

Prepared by

Mike McKann, Research Assistant

October 1970

for

COASTAL RESOURCES MANAGEMENT PROGRAM

INTERAGENCY NATURAL RESOURCES COUNCIL

DIVISION OF PLANNING COORDINATION

OFFICE OF THE GOVERNOR

CONTENTS

LAND OWNERSHIP
IN THE COASTAL ZONE

FOREWARD

In May of 1970, the Interagency Natural Resources Council initiated the Texas Coastal Resources Management Program. The initial objective was the production of an Interim Report for the 62nd Legislature by December, 1970, identifying existing conditions and problems in the State's Coastal Zone.

The overall task was broken down into twenty-one study areas, each one assigned to some qualified group for preparation of a brief summary report. Land Ownership in the Coastal Zone represents one of those areas and has been performed by staff provided by the Governor's Division of Planning Coordination, with the cooperation of many other governmental groups.

An inventory of land ownership patterns in the Coastal Zone is needed as an essential planning tool for the Coastal Resources Management Program. Such an inventory has never been undertaken in a systematic and comprehensive fashion. This report is only a preliminary step in that direction, since time constraints permitted only a general picture of Coastal Zone land ownership.

The Report is made possible only through the full cooperation of the State agencies and commissions, counties, and other parties who contributed of their time and knowledge. A special thanks is extended to the staffs of the General Land Office and the Texas Parks and Wildlife Department, and to the County Tax Assessor-Collectors of Bee, Brazoria, Cameron, Chambers, Kleberg, Lavaca, Nueces, Victoria, Walker and Waller Counties for their assistance.

I. SYNOPSIS

Objectives

A record of ownership of the uplands and submerged lands along the Texas Gulf Coast has never been compiled *in a single file*. In some cases, State agencies have an inventory of land ownership which falls within their particular area of interest. However, *to plan effectively, a total mosaic of land ownership is essential*. It is hiped that eventually a Program can be developed which will culminate in a complete index of land ownership in the Coastal Zone.

This report sets forth only general patterns of land ownership. It is not intended to be detailed. In many cases it was necessary to approximate tract sizes and many categories of ownership suffer from incomplete information, although the major categories are adequately covered. The data are complete enough to give an overview of land ownership in the Texas Coastal Zone.

Assumptions and Methodology

It was necessary in this survey to define a boundary for the study area. In past planning efforts by the State of Texas, the State had been divided into twenty-one planning regions. Five of these regions border the Gulf of Mexico and are composed of several tiers of counties inland. Since these inland counties are within the sphere of coastal influence and have been included in previous coastal planning efforts, the study area was defined to include the five coastal planning regions (see enclosed figures).

The task was approached by dividing the ownership into four basic groups:

1. *Federal Government*
2. *State Government*
3. *Local Government*, and
4. *Private Owners*.

As the work of collecting data progressed, it became necessary to break these categories down further. Only the private ownership group was left as one figure. At a later date, perhaps the private ownership could be broken down as to the size of land parcels owned by an individual.

To get the most up-to-date information, each county tax assessor-collector was asked for specific land ownership data in his county. They were to supply the number of acres and the location of the land parcels owned by each sub-group in the four basic categories. The information which was received proved very useful. Unfortunately only partial coverage was obtained in this manner. The remaining needed data was obtained from State agencies and from the various landowners themselves.

The General Land Office and the Parks and Wildlife Department provided the majority of the information on State and local government land ownership. The General Land Office had published total acreage figures for the land area, submerged lands and islands, and river beds acreage in each Texas county. Due to the inconsistency of information sources, these figures were used throughout the report when conflicts arose to achieve a uniform degree of accuracy.

Some explanation of the method of calculating the number of acres should be made. In the three categories of public ownership - federal, State, and local - each figure was derived from official sources. To calculate the total land area under private ownership in each county, the other categories were totaled, then subtracted from the grand total of acres in the county, the remainder being that area under private ownership. By this method, it must be understood that as the other categories become more complete, the "private" category will have an equivalent decrease in acres.

Limitations

The report was limited by three major factors, two being *time* and *manpower*. The eqivalent of two man-months was spent gathering and compiling the information presented herein. The third limitation was the *availability of information*. In some cases, as with the school districts, there has never been a list of the amount of land owned by them. So, to collect this information each of the school districts in the 36-county study area would have to be contacted individually. Also, much of the material which *has* been collected is out-of-date, and where there are two or more sources available a difference in total acreage is not uncommon. This discrepancy will necessitate a more thorough and exhaustive inventory involving personal investigation at the local level.

Summary of Findings

The uplands and submerged lands and islands in the Texas Coastal Zone cover a total of *25,394,003 acres*. Of this, *the Federal government owns about 2%, the State of Texas 16%, local governments 2%, and the private owners 80%.*

The majority of the Federal lands falls under the sub-category "Parks and Refuges" with "Military Installations" comprising most of the remainder. The only other basic category falling below two percent of the total is that of the local governments. However, this category will see an increase as more information becomes available.

The two major landholders are the private owners and the State of Texas. The private landowners hold approximately 20½ million acres of our Coastal Zone and the *State about 4 million acres*. However, nearly 93% of the State-owned lands are submerged lands and islands.

Problems and Recommendations

The history of Texas has been relatively short, but fast-changing and colorful. In the forty years prior to 1860, the people of this area experienced the rule of Spain and Mexico, sovereignty as an independent nation, and Statehood in the United States of America. Land ownership through this period and up to the present has undergone similar turmoil and all the problems which accompany it. As the future unfolds and population increases, our *land laws will need to be more definitive*. Some of the problems related to land ownership will be presented here with possible solutions.

The first area of concern is that of *keeping an inventory of Texas land ownership*. The General Land Office is the logical agency to keep such an inventory and does so already, to an extent. However, the present records cannot be read and interpreted by the layman. The information should be depicted on maps having common landmarks (e.g., Texas Highway Department county maps) and be readily available to the public and to other State agencies. This would provide a much needed planning tool for resource planners, and others interested in knowing ownership patterns.

The Coastal Zone is in constant natural change in addition to the changes man has caused. The phenomenon of *acretion and erosion* has caused many disputes over who gained and who lost land area. *The present laws have invariably left some questions unanswered.* For example, the courts ruled (*Lutes v. State*) that if acretion was built up from the land seaward, the individual possessing riparian or littoral rights was the owner, but if the new land built up from the bottom of State-owned land then it belongs to the State. However, it is a scientific fact that all areation builds up from the bottom, and this was overlooked by the courts. Also, acretion is being caused artificially by dams and other constructions of man. There is frequently disagreement on determining the cause of acretion. So, in summary, *how should acreted land be divided between the littoral property owners and the State?* It seems a possible solution to freeze present boundaries leaving new acretions under State ownership. The adjoining owner could make use of the land, but without the right to restrict its use by others or building any permanent structures which would obstruct passage through it. This could be a potential source for recreation lands.

On the other hand is erosion. The law of erosion is the reciprocal of the law of acretion, as would be expected. The landowner is deprived of land subject to natural and imperceptible erosion. "Submersion" of an owner's land, however, does not deprive him of his right to the land and he may reclaim it by land filling. This decision (Fitzgerald v. Boyles) has been used to the advantage of developers who are filling in land well out into Galveston Bay.[1] To prevent this misuse stricter definition and policing at the local level are needed.

Another problem in boundary location is that of *actually defining the boundary between littoral property and State-owned submerged lands*. Due to the diversity of the shoreline topography

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[1]*"Footprints...on the Sands of Time," Report of the Interim Beach Study Committee, 1970, p. 28.*

along the 1,081 miles of Texas Gulf Coast, it is difficult to apply *one universal set rule* in locating a boundary line. The present method of establishing the mean high-tide line as the boundary is expensive and time consuming. This problem has existed many years and many solutions have been proposed. Thus, a solution drawn from so cursory an investigation would prove unfruitful, and should, therefore, be studied more comprehensively in the long run.

Another closely related area which needs clarification is *property rights of the individuals owning land along the waters of Texas*. "Riparian rights" has been used widely to refer not only to the lands adjacent to rivers but lakes, ponds, and tidal waters. Texas landowners have littoral rights - those accrued to landowners along the coast - but these have not been defined. There *is also no indication that littoral rights include all the privileges of riparian owners*. A particular privilege in question is the right to build a pier out into the water - one which is held by riparian owners. There have only been two restrictions, and only one specifically mentioning piers, which have had any affect on the littoral right to build piers. The Corps of Engineers must approve all piers built into the Gulf of Mexico. The *Reagan de la Garza Act* provides for the leasing and development of submerged lands for industrial purposes only, which lays some doubt on the rights of littoral owners. *A statement of public policy must be given on this situation.* Perhaps the State should require an application and fee to obtain an easement for a pier over State-owned waters.

The concept of *compensating the State of Texas for use of its public lands could and should be carried further*. Many of the State-owned natural islands and spoil islands are dotted with small fishing shacks. It is a fact pointed out in the Interim Beach Study Committee's Report, *Footprints...on the Sands of Time*"[2] and the Department of Interior's report on *Laguna Atascosa National Wildlife Refuge*.[3] Continuing this practice would fulfill a recreational need and make use of a valuable recreation resource. However, such use of State property is unlawful by present statutes. Legislation could be drawn up requiring an application and rental fee for an easement on which to build. Building codes would have to be imposed to insure quality in respect to safety and esthetics, and a policing force would have to be funded.

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[2]*"Footprints...on the Sands of Time," Report of the Interim Beach Study Committee, 1970, p. 26.*

[3]*Laguna Atascosa Wilderness Study Area," Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, 1970.*

Finally, a major problem related to planning in the State agencies has become evident in the course of the land ownership inventory. *There is not enough coordination between the agencies to get a good overall effect in planning.* A pipeline easement may be made without any regard to what other elements exist in the area. Furthermore, in the granting of such an easement it is impossible to refer to a collective source to find out what must co-exist in a given area. Within the General Land Office, records and maps should be kept showing every element and activity which exists in and on the State-owned lands and waters. This would include telephone, telegraph, and power lines, oil, gas, and sulphur pipelines, irrigation and water pipelines, shell dredging areas, shipping lanes, and the numerous other activities. Major activities (e.g., industry) in adjacent areas should be included if they have significant influence on the environment. With such a facility at the disposal of planners, the effects of their planning could be much more thoroughly analyzed beforehand and hopefully fewer environmental blunders would be made.

Certainly these are not all the problems which must be solved in the Coastal Zone, but they are the most urgent at present relating to land ownership. Their successful solutions are essential to insuring a balance between the economic development and conservation of the resources of the Texas Coastal Zone.

II. SUMMARY DATA OF CATEGORIES

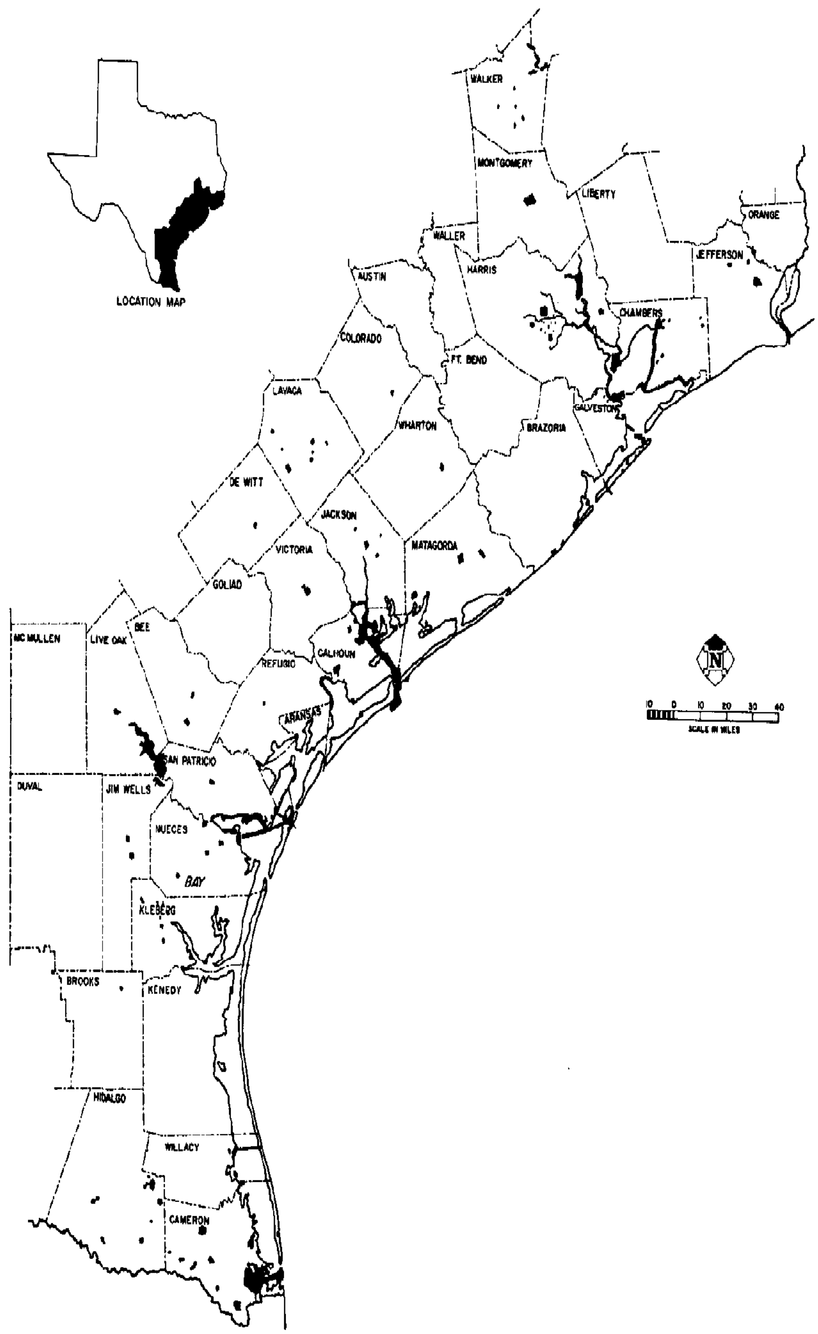
Introduction

The material presented in this section summarizes the Federal, State, Local, and Private land ownership quantitatively and pictorially. The maps show at a glance the location of ownership in each category within the total study area.

Total Acreage By Category

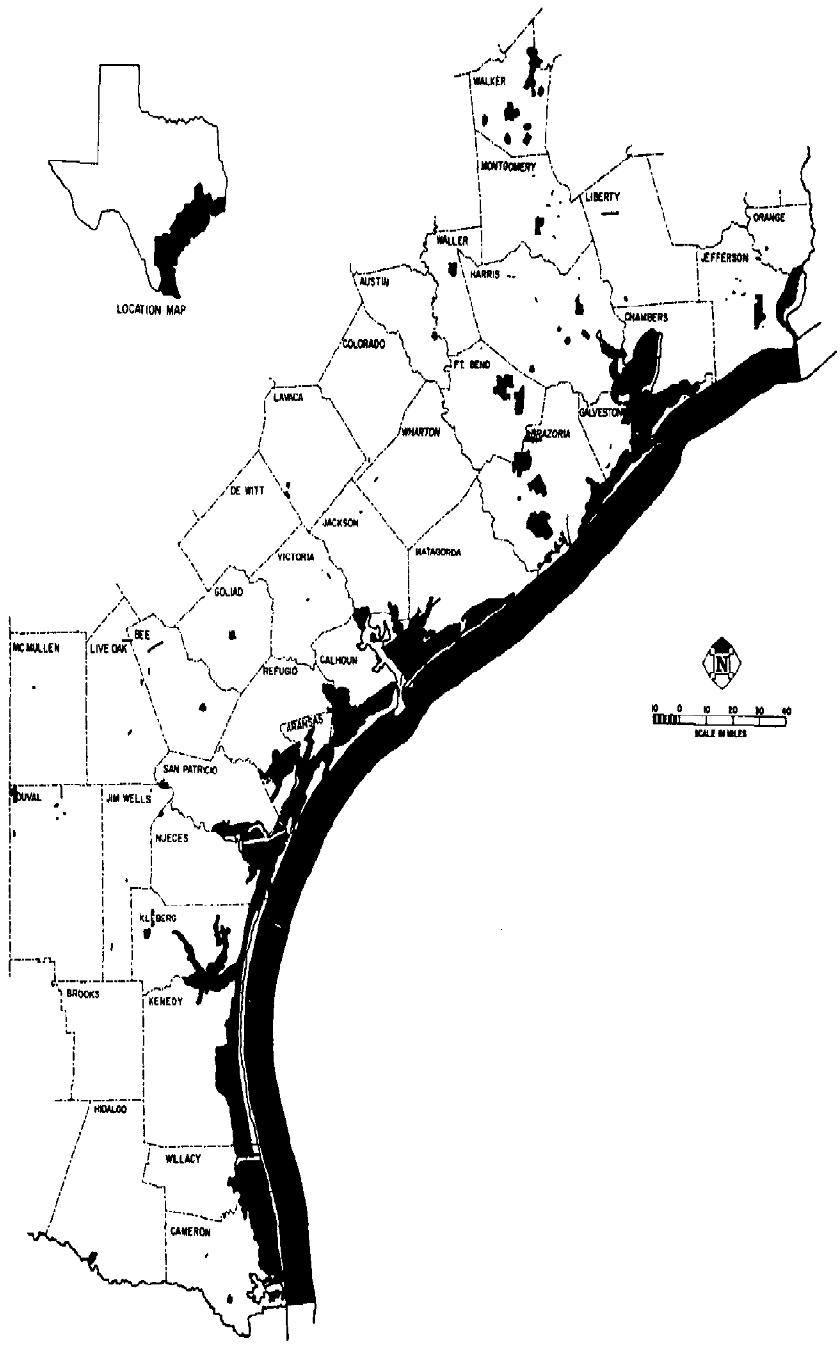
	Acres	Percentage of Total
FEDERAL	450,532	1.77%
STATE	4,156,735	16.36%
LOCAL	388,803	1.53%
PRIVATE	20,398,433	80.32%
TOTAL ACREAGE	25,394,003	

NOTE: of the 4,156,735 State-owned acres, 3,858,522 acres or 92.83% are submerged lands and islands.



LOCAL GOVERNMENTS LAND OWNERSHIP

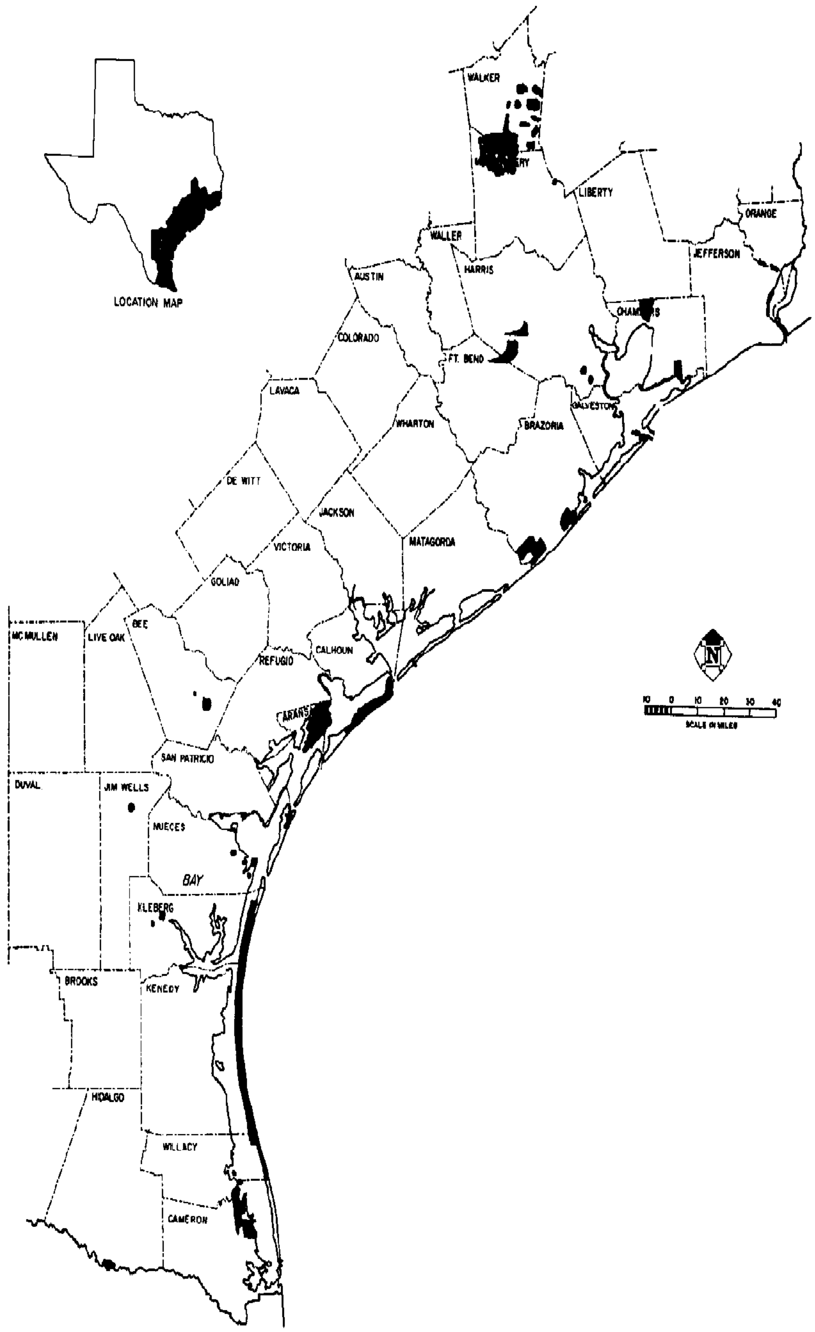
WITHOUT SCHOOL DISTRICTS PROPERTY



STATE LAND OWNERSHIP

WITHOUT ROADS AND HIGHWAYS PROPERTY

OR RIVER BEDS ACREAGE



FEDERAL LAND OWNERSHIP

LAND OWNERSHIP

COUNTY: Aransas

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			54,523
A. Corps of Engineers	.2 mile	100	
B. Parks, Refuges, etc.	31.0 miles	54,423	
C. Military Installations	8.5 miles	--	
D. Other			
II. STATE			236,885
A. Public Free School Land		137	
B. Roads & Highways		1,048	
C. State Prison Lands		--	
D. State Parks, etc.	3.1 miles	313	
E. Submerged Lands & Islands		235,337	
F. River Beds Acreage		50	
G. University & College Campuses			
H. Other			
III. LOCAL			2,768
A. River Authorities			
B. Navigation Districts		1,623	
C. Water Districts			
D. Counties			
1. Parks	1.0 mile	67	
2. Roads		467	
3. Airports		600	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		11	
2. Airports		--	
3. Other			
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			106,763
		Grand Total	400,939

LAND OWNERSHIP

COUNTY: Austin

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			4,804
A. Public Free School Land			
B. Roads & Highways		3,340	
C. State Prison Lands		--	
D. State Parks, etc.		664	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		800	
G. University & College Campuses			
H. Other			
III. LOCAL			2,757
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		2,743	
3. Airports			
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		14	
2. Airports		--	
3. Other			
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			397,483
		Grand Total	405,044

LAND OWNERSHIP

COUNTY: Bee

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			1,809
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		1,809	
D. Other			
II. STATE			5,243
A. Public Free School Land		351	
B. Roads & Highways		3,742	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		700	
G. University & College Campuses			
H. Other		450	
III. LOCAL			2,224
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		1,912	
3. Airports			
4. Junior Colleges		100	
5. Other			
E. Cities			
1. Parks		52	
2. Airports		160	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			544,986
		Grand Total	554,262

LAND OWNERSHIP

COUNTY: Brazoria

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			21,311
A. Corps of Engineers		12	
B. Parks, Refuges, etc.	29.5 miles	21,299	
C. Military Installations		--	
D. Other			
II. STATE			272,351
A. Public Free School Land		104	
B. Roads & Highways		5,440	
C. State Prison Lands		37,429	
D. State Parks, etc.	5.4 miles	1,141	
E. Submerged Lands & Islands		223,837	
F. River Beds Acreage		4,400	
G. University & College Campuses			
H. Other			
III. LOCAL			5,516
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		461	
2. Roads		4,329	
3. Airports			
4. Junior Colleges		177	
5. Other			
E. Cities			
1. Parks		549	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			830,042
		Grand Total	1,129,220

LAND OWNERSHIP

COUNTY: Brooks

		WATERFRONTAGE	ACREAGE SUB-TOTAL	TOTAL
I.	FEDERAL			0
	A. Corps of Engineers		--	
	B. Parks, Refuges, etc.		--	
	C. Military Installations		--	
	D. Other			
II.	STATE			1,695
	A. Public Free School Land		--	
	B. Roads & Highways		1,695	
	C. State Prison Lands		--	
	D. State Parks, etc.		--	
	E. Submerged Lands & Islands		--	
	F. River Beds Acreage		--	
	G. University & College Campuses			
	H. Other			
III.	LOCAL			779
	A. River Authorities		--	
	B. Navigation Districts		--	
	C. Water Districts		--	
	D. Counties			
	1. Parks		--	
	2. Roads		569	
	3. Airports		164	
	4. Junior Colleges			
	5. Other			
	E. Cities			
	1. Parks		46	
	2. Airports		--	
	3. Other		--	
	F. School Districts		Incomplete	
	G. Other			
IV.	PRIVATE			603,724
			Grand Total	606,198

LAND OWNERSHIP

COUNTY: Calhoun

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			19,900
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		1,100	
C. Military Installations	79.0 miles	18,800	
D. Other			
II. STATE			447,478
A. Public Free School Land		149	
B. Roads & Highways		2,464	
C. State Prison Lands		--	
D. State Parks, etc.	1.0 mile	351	
E. Submerged Lands & Islands		444,214	
F. River Beds Acreage		300	
G. University & College Campuses			
H. Other			
III. LOCAL			51,291
A. River Authorities		--	
B. Navigation Districts		50,188	
C. Water Districts		--	
D. Counties			
1. Parks	1.6 miles	40	
2. Roads		766	
3. Airports		200	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		22	
2. Airports		--	
3. Other		75	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			299,312
		Grand Total	817,981

LAND OWNERSHIP

COUNTY: Cameron

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			45,690
A. Corps of Engineers		28	
B. Parks, Refuges, etc.	25.0 miles	45,147	
C. Military Installations		--	
D. Other		565	
II. STATE			336,534
A. Public Free School Land		--	
B. Roads & Highways		7,083	
C. State Prison Lands		--	
D. State Parks, etc.	1.5 miles	720	
E. Submerged Lands & Islands		326,753	
F. River Beds Acreage		1,900	
G. University & College Campuses			
H. Other		78	
III. LOCAL			49,208
A. River Authorities		--	
B. Navigation Districts		32,699	
C. Water Districts		5,229	
D. Counties			
1. Parks	1.0 mile	164	
2. Roads		5,186	
3. Airports		826	
4. Junior Colleges		45	
5. Other			
E. Cities			
1. Parks		250	
2. Airports		3,241	
3. Other		568	
F. School Districts		1,000	
G. Other			
IV. PRIVATE			520,652
		Grand Total	952,084

LAND OWNERSHIP

COUNTY: Chambers

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			24,605
A. Corps of Engineers		14,269	
B. Parks, Refuges, etc.	6.5 miles	10,336	
C. Military Installations		--	
D. Other			
II. STATE			136,946
A. Public Free School Land		36	
B. Roads & Highways		3,289	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		130,221	
F. River Beds Acreage		3,400	
G. University & College Campuses			
H. Other			
III. LOCAL			80,825
A. River Authorities		--	
B. Navigation Districts		36,813	
C. Water Districts		1	
D. Counties			
1. Parks	1,900 feet	285	
2. Roads		1,098	
3. Airports		216	
4. Junior Colleges			
5. Other		20,297	
E. Cities			
1. Parks		--	
2. Airports		--	
3. Other		5	
F. School Districts		201	
G. Other		13	
IV. PRIVATE			340,009
		Grand Total	582,385

LAND OWNERSHIP

COUNTY: Colorado

	WATERFRONTAGE	ACREAGE SUB-TOTAL	TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			6,227
A. Public Free School Land		31	
B. Roads & Highways		3,696	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		2,500	
G. University & College Campuses			
H. Other			
III. LOCAL			3,658
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		3,201	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		232	
2. Airports		215	
3. Other		10	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			593,440
		Grand Total	603,325

LAND OWNERSHIP

COUNTY: Dewitt

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			5,254
A. Public Free School Land		--	
B. Roads & Highways		4,354	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		900	
G. University & College Campuses			
H. Other			
III. LOCAL			3,585
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		3,345	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		165	
2. Airports		75	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			558,337
		Grand Total	567,176

LAND OWNERSHIP

COUNTY: Duval

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			6,933
A. Public Free School Land		2,760	
B. Roads & Highways		4,173	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		--	
G. University & College Campuses			
H. Other			
III. LOCAL			2,361
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks		--	
2. Roads		2,355	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		6	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			1,119,472
		Grand Total	1,128,766

LAND OWNERSHIP

COUNTY: Fort Bend

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			7,699
A. Corps of Engineers		7,699	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			18,009
A. Public Free School Land		17	
B. Roads & Highways		4,532	
C. State Prison Lands		10,860	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		2,600	
G. University & College Campuses			
H. Other			
III. LOCAL			3,508
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts			
D. Counties			
1. Parks		--	
2. Roads		3,425	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		83	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			534,273
		Grand Total	563,489

LAND OWNERSHIP

COUNTY: Galveston

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			2,458
A. Corps of Engineers	6.6 miles	2,458	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			560,156
A. Public Free School Land		409	
B. Roads & Highways		3,437	
C. State Prison Lands		--	
D. State Parks, etc.		1,922	
E. Submerged Lands & Islands		553,988	
F. River Beds Acreage		400	
G. University & College Campuses			
H. Other			
III. LOCAL			6,815
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks	10.0 miles	1,797	
2. Roads		1,800	
3. Airports			
4. Junior Colleges		114	
5. Other			
E. Cities			
1. Parks		683	
2. Airports		1,766	
3. Other		655	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			240,192
		Grand Total	809,621

LAND OWNERSHIP

COUNTY: Goliad

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			4,714
A. Public Free School Land		--	
B. Roads & Highways		3,089	
C. State Prison Lands		--	
D. State Parks, etc.		225	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		1,400	
G. University & College Campuses			
H. Other			
III. LOCAL			1,460
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks		--	
2. Roads		1,460	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		--	
2. Airports		--	
3. Other		Incomplete	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			546,232
		Grand Total	552,406

LAND OWNERSHIP

COUNTY: Harris

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			30,126
A. Corps of Engineers		26,306	
B. Parks, Refuges, etc.		--	
C. Military Installations		3,820	
D. Other			
II. STATE			13,060
A. Public Free School Land		152	
B. Roads & Highways		7,365	
C. State Prison Lands		295	
D. State Parks, etc.		2,974	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		1,600	
G. University & College Campuses		329	
H. Other			
III. LOCAL			29,897
A. River Authorities		1,407	
B. Navigation Districts		3,769	
C. Water Districts		--	
D. Counties			
1. Parks		3,071	
2. Roads		8,483	
3. Airports			
4. Junior Colleges		193	
5. Other			
E. Cities			
1. Parks		4,370	
2. Airports		8,604	
3. Other		12,240	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			1,026,962
		Grand Total	1,100,045

LAND OWNERSHIP

COUNTY: Hidalgo

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			1,981
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		1,981	
C. Military Installations		--	
D. Other			
II. STATE			10,961
A. Public Free School Land		--	
B. Roads & Highways		9,228	
C. State Prison Lands		--	
D. State Parks, etc.		588	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		1,100	
G. University & College Campuses		45	
H. Other			
III. LOCAL			10,539
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		3,277	
D. Counties			
1. Parks		1,026	
2. Roads		8,098	
3. Airports			
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		449	
2. Airports		966	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			1,002,466
		Grand Total	1,025,947

LAND OWNERSHIP

COUNTY: Jackson

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			12,625
A. Public Free School Land		20	
B. Roads & Highways		3,784	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		6,821	
F. River Beds Acreage		2,000	
G. University & College Campuses			
H. Other			
III. LOCAL			3,413
A. River Authorities			
B. Navigation Districts		1,083	
C. Water Districts		--	
D. Counties			
1. Parks		35	
2. Roads		2,219	
3. Airports		70	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		6	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			518,657
		Grand Total	534,695

LAND OWNERSHIP

COUNTY: Jefferson

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			1,165
A. Corps of Engineers	10.0 miles	1,165	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			281,081
A. Public Free School Land		838	
B. Roads & Highways		3,921	
C. State Prison Lands		--	
D. State Parks, etc.		8,403	
E. Submerged Lands & Islands		266,245	
F. River Beds Acreage		1,500	
G. University & College Campuses		174	
H. Other			
III. LOCAL			17,541
A. River Authorities		Incomplete	
B. Navigation Districts		64	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		1,802	
3. Airports		1,139	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		3,005	
2. Airports		276	
3. Other		11,255	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			587,761
		Grand Total	887,548

LAND OWNERSHIP

COUNTY: Jim Wells

	WATERFRONTAGE	ACREAGE SUB-TOTAL	TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		Incomplete	
D. Other			
II. STATE			3,947
A. Public Free School Land		157	
B. Roads & Highways		3,690	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		100	
G. University & College Campuses			
H. Other			
III. LOCAL			3,894
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		880	
D. Counties			
1. Parks		--	
2. Roads		2,287	
3. Airports			
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		171	
2. Airports		556	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			548,491
		Grand Total	556,332

LAND OWNERSHIP

COUNTY: Kenedy

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			93,646
A. Corps of Engineers		--	
B. Parks, Refuges, etc.	47.5 miles	93,646	
C. Military Installations		--	
D. Other			
II. STATE			441,196
A. Public Free School Land		--	
B. Roads & Highways		678	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		440,438	
F. River Beds Acreage		80	
G. University & College Campuses			
H. Other			
III. LOCAL			29
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		29	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		--	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			868,398
		Grand Total	1,403,269

LAND OWNERSHIP

COUNTY: Kleberg

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			35,183
A. Corps of Engineers		--	
B. Parks, Refuges, etc.	20.0 miles	31,423	
C. Military Installations		3,760	
D. Other			
II. STATE			221,464
A. Public Free School Land		--	
B. Roads & Highways		1,988	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		218,013	
F. River Beds Acreage		200	
G. University & College Campuses		1,263	
H. Other			
III. LOCAL			2,145
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks	0.7 mile	260	
2. Roads		681	
3. Airports		263	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		11	
2. Airports		--	
3. Other		930	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			509,322
		Grand Total	768,114

LAND OWNERSHIP

COUNTY: Lavaca

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			5,849
A. Public Free School Land		0	
B. Roads & Highways		4,266	
C. State Prison Lands		0	
D. State Parks, etc.		0	
E. Submerged Lands & Islands		0	
F. River Beds Acreage		1,500	
G. University & College Campuses		83	
H. Other			
III. LOCAL			4,787
A. River Authorities		2	
B. Navigation Districts			
C. Water Districts			
D. Counties			
1. Parks			
2. Roads		3,886	
3. Airports			
4. Junior Colleges			
5. Other		180	
E. Cities			
1. Parks		364	
2. Airports		151	
3. Other		91	
F. School Districts		113	
G. Other			
IV. PRIVATE			568,101
		Grand Total	578,737

LAND OWNERSHIP

COUNTY: Liberty

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		Incomplete	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			9,586
A. Public Free School Land		464	
B. Roads & Highways		5,022	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		4,100	
G. University & College Campuses			
H. Other			
III. LOCAL			2,497
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks		--	
2. Roads		2,367	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		13	
2. Airports		117	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			727,308
		Grand Total	739,391

LAND OWNERSHIP

COUNTY: Live Oak

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		Incomplete	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			5,258
A. Public Free School Land		235	
B. Roads & Highways		4,352	
C. State Prison Lands		--	
D. State Parks, etc.		31	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		640	
G. University & College Campuses			
H. Other			
III. LOCAL			2,103
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks		--	
2. Roads		2,055	
3. Airports		12	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		36	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			651,529
		Grand Total	658,890

LAND OWNERSHIP

COUNTY: Matagorda

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			75
A. Corps of Engineers		75	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			571,918
A. Public Free School Land		502	
B. Roads & Highways		4,296	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		564,820	
F. River Beds Acreage		2,300	
G. University & College Campuses			
H. Other			
III. LOCAL			6,651
A. River Authorities		Incomplete	
B. Navigation Districts		2,118	
C. Water Districts		Incomplete	
D. Counties			
1. Parks	1,200 feet	Incomplete	
2. Roads		2,554	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		301	
2. Airports		1,678	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			707,978
		Grand Total	1,286,622

LAND OWNERSHIP

COUNTY: McMullen

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			2,561
A. Public Free School Land		64	
B. Roads & Highways		2,027	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		470	
G. University & College Campuses			
H. Other			
III. LOCAL			777
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks		--	
2. Roads		777	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		--	
2. Airports		--	
3. Other		Incomplete	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			737,557
		Grand Total	740,895

LAND OWNERSHIP

COUNTY: Montgomery

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			46,324
A. Corps of Engineers		Incomplete	
B. Parks, Refuges, etc.		46,324	
C. Military Installations		--	
D. Other			
II. STATE			8,767
A. Public Free School Land		358	
B. Roads & Highways		4,692	
C. State Prison Lands		--	
D. State Parks, etc.		1,709	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		600	
G. University & College Campuses		1,408	
H. Other			
III. LOCAL			25,750
A. River Authorities		20,985	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		3,464	
3. Airports		1,277	
4. Junior Colleges			
5. Other			
E. Cities			
1. Parks		24	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			611,451
		Grand Total	692,292

LAND OWNERSHIP

COUNTY: Nueces

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			3,054
A. Corps of Engineers	0.2 mile	110	
B. Parks, Refuges, etc.		--	
C. Military Installations	8.5 miles	2,944	
D. Other			
II. STATE			274,013
A. Public Free School Land			
B. Roads & Highways		5,793	
C. State Prison Lands		--	
D. State Parks, etc.		5	
E. Submerged Lands & Islands		267,875	
F. River Beds Acreage		340	
G. University & College Campuses			
H. Other			
III. LOCAL			29,428
A. River Authorities		--	
B. Navigation Districts		20,022	
C. Water Districts		--	
D. Counties			
1. Parks	3,900 feet	686	
2. Roads		3,650	
3. Airports		220	
4. Junior Colleges		159	
5. Other			
E. Cities			
1. Parks	3.0 miles	923	
2. Airports		2,075	
3. Other		1,693	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			513,845
		Grand Total	820,340

LAND OWNERSHIP

COUNTY: Orange

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			6,034
A. Public Free School Land		45	
B. Roads & Highways		2,537	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		1,852	
F. River Beds Acreage		1,600	
G. University & College Campuses			
H. Other			
III. LOCAL			1,286
A. River Authorities		Incomplete	
B. Navigation Districts		3	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		1,181	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		102	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			234,193
		Grand Total	241,513

LAND OWNERSHIP

COUNTY: Refugio

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			240
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		240	
C. Military Installations		--	
D. Other			
II. STATE			21,480
A. Public Free School Land		100	
B. Roads & Highways		2,680	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		16,800	
F. River Beds Acreage		1,900	
G. University & College Campuses			
H. Other			
III. LOCAL			823
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		Incomplete	
D. Counties			
1. Parks	1,500 feet	Incomplete	
2. Roads		781	
3. Airports		--	
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		42	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			495,219
		Grand Total	517,762

LAND OWNERSHIP

COUNTY: San Patricio

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			19,892
A. Public Free School Land		971	
B. Roads & Highways		4,267	
C. State Prison Lands		--	
D. State Parks, etc.		14,188	
E. Submerged Lands & Islands		66	
F. River Beds Acreage		400	
G. University & College Campuses			
H. Other			
III. LOCAL			3,535
A. River Authorities		--	
B. Navigation Districts		230	
C. Water Districts		Incomplete	
D. Counties			
1. Parks		--	
2. Roads		2,828	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks	1,200 feet	242	
2. Airports		235	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			456,811
		Grand Total	480,238

LAND OWNERSHIP

COUNTY: Victoria

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			4
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		4	
D. Other			
II. STATE			5,330
A. Public Free School Land		146	
B. Roads & Highways		3,384	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		1,800	
G. University & College Campuses			
H. Other			
III. LOCAL			6,024
A. River Authorities		--	
B. Navigation Districts		335	
C. Water Districts		6	
D. Counties			
1. Parks		--	
2. Roads		2,978	
3. Airports		2,104	
4. Junior Colleges		60	
5. Other		21	
E. Cities			
1. Parks		421	
2. Airports		--	
3. Other		180	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			578,818
		Grand Total	590,176

LAND OWNERSHIP

COUNTY: Walker

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			53,461
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		53,461	
C. Military Installations		--	
D. Other			
II. STATE			20,180
A. Public Free School Land		17	
B. Roads & Highways		3,993	
C. State Prison Lands		11,616	
D. State Parks, etc.		2,369	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		1,000	
G. University & College Campuses		1,185	
H. Other			
III. LOCAL			3,986
A. River Authorities		1,328	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		1,825	
3. Airports			
4. Junior Colleges			
5. Other		5	
E. Cities			
1. Parks		--	
2. Airports		99	
3. Other		629	
F. School Districts		100	
G. Other			
IV. PRIVATE			438,957
		Grand Total	516,584

LAND OWNERSHIP

COUNTY: Waller

	WATERFRONTAGE	ACREAGE SUB-TOTAL	TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			5,694
A. Public Free School Land		0	
B. Roads & Highways		2,886	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		1,400	
G. University & College Campuses		1,408	
H. Other			
III. LOCAL			6,057
A. River Authorities		--	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		2,140	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		17	
2. Airports		--	
3. Other		3,900	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			319,372
		Grand Total	331,123

LAND OWNERSHIP

COUNTY: Wharton

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			0
A. Corps of Engineers		--	
B. Parks, Refuges, etc.		--	
C. Military Installations		--	
D. Other			
II. STATE			8,571
A. Public Free School Land		313	
B. Roads & Highways		5,073	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		--	
F. River Beds Acreage		2,000	
G. University & College Campuses		1,185	
H. Other			
III. LOCAL			4,694
A. River Authorities		Incomplete	
B. Navigation Districts		--	
C. Water Districts		--	
D. Counties			
1. Parks		--	
2. Roads		4,502	
3. Airports			
4. Junior Colleges		82	
5. Other			
E. Cities			
1. Parks		11	
2. Airports		99	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			672,074
		Grand Total	685,339

LAND OWNERSHIP

COUNTY: Willacy

	WATERFRONTAGE	ACREAGE SUB-TOTAL	ACREAGE TOTAL
I. FEDERAL			7,278
A. Corps of Engineers		Incomplete	
B. Parks, Refuges, etc.	13.5 miles	7,278	
C. Military Installations		--	
D. Other			
II. STATE			164,039
A. Public Free School Land		0	
B. Roads & Highways		2,697	
C. State Prison Lands		--	
D. State Parks, etc.		--	
E. Submerged Lands & Islands		161,242	
F. River Beds Acreage		100	
G. University & College Campuses			
H. Other			
III. LOCAL			5,692
A. River Authorities		--	
B. Navigation Districts		3,249	
C. Water Districts		Incomplete	
D. Counties			
1. Parks	800 feet	Incomplete	
2. Roads		2,440	
3. Airports			
4. Junior Colleges			
5. Other		--	
E. Cities			
1. Parks		3	
2. Airports		--	
3. Other		--	
F. School Districts		Incomplete	
G. Other			
IV. PRIVATE			388,246
		Grand Total	565,255